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Revision 1

Technical Evaluation Of The Application, Storage, And Transportation Of Polyurea-Coated Containers

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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T. S. Vail
Fluor Hanford, Inc.

J. B. Woodbury
Fluor Hanford, Inc.

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EXECUTIVE SUMMARY

This technical report evaluates the benefits, concerns, and limitations of using polyurea coatings on waste containers at the Hanford Site. Specifically addressed are the storage, handling, and application of the polyurea and the onsite transportation of waste containers (e.g. drums, wooden boxes, fiberglass-reinforced plywood or metal boxes, tanks, casks, or other containers) having a polyurea coating. The function of a polyurea coating is to minimize the potential for the spread of surface contamination from a waste package, thereby protecting workers and the environment, and/or to protect the package from environmental elements during outdoor storage. The conclusions derived from this report are that polyurea, when properly applied to the exterior of waste containers, does not impact the ability to safely transport containers and provides the Hanford Site with effective contamination control and/or environmental protection for the outside storage of waste containers.

A polyurea coating/elastomer is defined as the reaction product of an isocyanate component and a resin blend component. Polyurea has many industrial applications. Its commercial use on bridges, roof coverings, tanks, marine applications, waste water treatment, and other outdoor applications qualitatively defends the materials' resistances to environmental elements for long periods. Its primary uses at the Hanford Site are as a fixative for surface contamination and for environmental protection. Many coating systems are available, such as paints, urethanes, epoxies, and asphalted coatings. However, the polyurea technology was chosen for its physical properties, such as elasticity, water vapor transmission (permeance), crack bridging, hardness, adhesion to various materials, coefficient of linear expansion, impact resistance, tear strength, tensile elongation, and tensile strength over a large temperature range and humidity. Properly applied polyurea has an advantage over other products in that it dries quickly and can be handled within minutes of application.

Present waste container management practices achieve containment of radioactive contamination by placing contaminated steel or wooden containers inside another larger overpack. Polyurea coatings can be applied to structurally sound or unsound containers for contamination control, protection of the environment, and protection of the containers from the environment. When used for these purposes, polyurea can reduce the number of overpacks needed for long-term outdoor storage of waste containers. It follows then that there will be a proportional reduction in overpack-related handling operations and associated personnel exposures. Because overpacks are larger than the degraded containers they protect, substituting polyurea for overpacks also avoids an increase in waste volume. By avoiding repackaging operations and minimizing waste volumes, long-term waste operation costs are likely to be reduced.

A coating of polyurea on containers does not affect existing waste container operations. Polyurea is transparent to X rays, so nondestructive examination and nondestructive assay systems will still be effective. The coatings are compatible with existing container handling equipment and practices. Polyurea is easily cut with the same variety of tools (circular, reciprocating, or hole saws) now used in container operations. Industrial hazards associated with cured polyurea are addressed under existing Fluor Hanford, Inc., safety management programs.

Typical product Material Safety Data Sheets describing health hazards state that personal protective equipment is required for handling and spraying Parts A and B chemicals. The components exhibit reactive characteristics with water, alcohol, amines, acids, and bases that require separation from these materials during storage and handling. The isocyanate Part A will be transported as a U.S. Department of Transportation Hazard Class 9 material and should not be stored in areas with fire suppression equipment that utilize water. Part B is not regulated.

The cured product does not exhibit any unusual fire-fighting hazard, and the combustion products are carbon monoxide and oxides of nitrogen along with trace amounts of hydrogen chloride and hydrogen cyanide. Other products that could be present are sulfur dioxide, hydrogen fluoride, ammonia, aldehydes, and keytones. These combustion products are consistent with those found in home appliances, sidings, insulation, trains, planes, and automobiles and are less toxic than what is typically found in Hanford waste containers. Standard Hanford fire-fighting personal protective equipment, including the use of a face shield and self-contained breathing apparatus, provides adequate protection of personnel responding to a fire involving cured polyurea or its components.

The shipment of all hazardous packages on the Hanford Site must comply with the transportation safety-basis documents for that packaging system. Compliance with the requirements, limitations, or controls described in the safety basis for a package system will not be relaxed or modified because of the application of polyurea. No credit is taken under transportation safety analyses for polyurea coatings to enhance or maintain any structural, thermal, containment, shielding, criticality, or gas-generating condition of a package. Facility Container Management Programs must determine if, for the purpose of shipping a container, an overpack is required prior to the polyurea application. Polyurea-coated containers to be shipped without overpacks must meet all structural requirements for transportation independent of, prior to, and after the application of the polyurea.

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LIST OF TERMS

CMP	Container Management Program
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
facility	In this document the term facility is intended to apply to all operations or projects.
FH	Fluor Hanford, Inc.
FRP	fiberglass-reinforced plywood
MSDS	Material Safety Data Sheet
NCT	normal conditions of transport
PPE	personal protective equipment
PSSD	package-specific safety document
QA	quality assurance
RL	U.S. Department of Energy, Richland Operations Office
SARAH	*Hanford Safety Analysis and Risk Assessment Handbook*
SWB	Standard Waste Box
TRU	transuranic
TSR	Technical Safety Requirement
UV	ultraviolet
VOC	volatile organic compound

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TECHNICAL EVALUATION OF THE APPLICATION, STORAGE, AND TRANSPORTATION OF POLYUREA-COATED CONTAINERS

1.0 GENERAL INFORMATION

1.1 INTRODUCTION

This technical report evaluates the benefits, concerns, and limitations of using polyurea compounds on the Hanford Site. The following are addressed:

- The storage, handling, processing, application, and curing of the two polyurea components
- The onsite transportation of waste containers (e.g. drums, wooden boxes, fiberglass-reinforced plywood [FRP] or metal boxes, tanks, casks, or other containers) that have an external application of polyurea coating for contamination control.

A benefit of polyurea coatings on structurally sound containers is the protection they provide from environmental effects, reducing the number of steel overpacks required and their associated cost. Quantitative data specific to the environmental impact for periods longer than 15 years are not readily available; however, the utilization of polyurea coatings on outside applications over this period has resulted in minimal effect on the elastomer with only a slight graying and loss of gloss observed. The commercial utilization of polyurea on bridges, roof covering, tanks, marine applications, waste water treatment, and other outdoor uses qualitatively defends the materials' resistances to environmental elements for much longer periods. Polyurea-coated waste containers are expected to be stored outside for less time than that which would cause degradation due to environmental exposure. It follows that environmentally protected containers constitute a reduced number of overpacks, which is directly proportional to fewer handling operations and personnel exposures, and less potential for container degradation and spread of contamination.

Polyurea is a two-part, elastomeric polymer based on reactive, amine-terminated resins and high-performance isocyanate prepolymers. It is a spray-applied, aromatic, coating system that will provide a confinement barrier against environmental conditions for penetrations that are not readily visible and functions as a fixative for surface contamination. This type of product is marketed by several companies with multiple formulations. However, the product selected for use at Hanford (HNF-21239, *SWOC Fire Hazards Analysis [FHA]*) must have a flame spread index per ASTM E84-00a, *Standard Test Method for Surface Burning Characteristics of Building Materials*, of less than or equal to 25, which is considered a Class A building material by the National Fire Protection Association. Personal protective equipment (PPE) is required during spraying, minimal PPE is required during handling, and no PPE is required for storage of polyurea-coated containers.

Several types of polyurea and other coating systems were evaluated for this Hanford application. Advantages of the polyurea coatings over other materials are the physical characteristics as well as the conditions under which the material can be applied. Appendices A and B provide vendor information and Material Safety Data Sheets (MSDS) for two polyurea coatings that demonstrate the multiple formulations resulting in similar physical qualities. The InstaCote[1] SE FR, Appendix B, is the Hanford-preferred coating because it has the desired fire retardant and other physical characteristics for the application thickness. Appendix A describes the Envirolastic[2] AR 415 and is provided for comparative purposes. The valued physical properties of the InstaCote SE FR, besides the fire resistance, include elasticity, water vapor transmission, adhesion to various materials, coefficient of linear expansion, impact resistance, tear strength, tensile elongation, and tensile strength and are addressed further in Section 2.0.

Radioactive waste retrieval, handling, processing, and onsite transportation activities ultimately require the movement of containers that are structurally sound, but may have potentially degraded confinement layers or surface contamination. To mitigate the prospect of spreading contamination during waste management activities, packages could be inserted into an overpack. The overpack provides a confinement barrier to the spread of radioactive contamination, but the supplemental structural strength is unnecessary for containers that satisfy the containment and structural requirements established in facility Container Management Programs (CMP); DOE/RL-2001-36, *Hanford Sitewide Transportation Safety Document*; and its packaging authorizations. For structurally degraded containers, the overpack will continue to provide the desired level of protection from loose radioactive contamination and the environment. Containers with corroded areas or small holes are covered with tape, plastic wrap, and other patches to help minimize the potential for contamination spread when these containers are placed into an overpack. In some cases, however, structurally stable containers can be coated with polyurea, and the physical characteristics of polyurea will provide a robust confinement barrier that adds protection for the workers and the environment.

The application of polyurea, when applied properly, does not prohibit a package from being inserted into an overpack. Polyurea does not contain radioactive isotopes, so does not contribute to the radiological source term confined in the container. The polyurea coating is not credited with providing additional structural strength to the original container or its overpack. The polyurea coated container that is not overpacked must meet the conditions of facility CMPs as described in facility Documented Safety Analyses, Technical Safety Requirements (TSR), and DOE/RL-2001-36 for sound integrity. Structurally sound containers with some surface contamination may be overpacked to prevent the spread of contamination. Polyurea applied to the exterior of the contaminated, but structurally sound containers, can provide a robust confinement barrier that may eliminate the need to overpack. Containers may or may not be sprayed with polyurea, but CMPs must determine if the structural integrity of a container requires it to be overpacked prior to the polyurea application. The robust confinement barrier provided by polyurea can prevent the spread of radioactive surface contamination and for a sound container will not require it to be placed into an overpack. But because the polyurea is not credited with enhancing the structure of a container the decision to place an unsound container into an overpack can not be changed based solely on the polyurea coating. The application of

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[1] InstaCote is a registered trademark of InstaCote, Inc., Erie, Michigan.
[2] Envirolastic is a registered trademark of Mobile Enterprises, Inc., Fort Worth, Texas.

polyurea is not credited with reducing the radiological dose consequences from postulated accident scenarios as analyzed in facility Documented Safety Analyses or DOE/RL-2001-36.

The impacts of processing waste containers were reviewed including nondestructive examination and nondestructive assay. There is no impact of a polyurea coating with regard to nondestructive examination in that the coating is transparent to the X-ray system. Similarly, the coating has no impact to a nondestructive assay system, whether it is a drum or a box. Processing coated drums, including movement and examination in gloveboxes, is not impacted by polyurea because it does not interfere with equipment that grasps the tops of drums for lifting, nor does it interfere with a forklift beak picker, which grasps drums from the side and locking ring. Processing coated drums that require handling in a glovebox may require cutting the polyurea. The vendor for InstaCote SE FR has extensive experience with cutting cured polyurea with a variety of cutting tools; i.e., circular, reciprocating, or hole saws. The vendor reports that there are no hazardous vapors given off and that cutting would pose no unusual problems or risks (see informal communication from T. Nachtman, InstaCote, to G. Dukelow, Fluor Hanford, Inc., dated March 23, 2007, in Appendix B).

Objects made of noncombustible building materials, such as concrete or metal including construction debris, that are coated with polyurea can be treated the same for disposal in the low-level burial grounds as objects that are not coated. Containers with polyurea coatings on the exterior shall be stored on noncombustible building materials; i.e., concrete floors, asphalt, metal pallets, or the ground.

The transportation of all packages on the Hanford Site must comply with the transportation safety-basis documents for that package. Compliance with the requirements, limitations, or controls described in the safety basis for a packaging system will not be relaxed or modified because of the application of polyurea. The coating may be used on drums, wooden boxes, FRP or metal boxes, tanks, casks, or other containers.

1.2 CONTROLS FOR THE STORAGE, APPLICATION, AND TRANSPORTATION OF POLYUREA

Facility Documented Safety Analyses, TSRs, Fire Hazard Analysis, Safety Management Programs, and other implemented procedures specify parameters, requirements, limitations, and controls that should expand and further define the following control set. The assumptions used to establish boundaries in this report should be implemented into facility procedures as appropriate. This control set is broken down into three sections: the storage, the application process of the spray, and the transport of coated containers. These sections apply to all areas on the Hanford Site.

1.2.1 Storage

1. The polyurea components shall be separated from chemicals as listed below.
   a. The isocyanate Part A shall be separated from water, alcohol, amines, acids, and bases.
   b. The resin Part B shall be separated from nitrites and may react violently with acids.
   c. The cured polyurea shall be separated from strong, concentrated acids.
2. The isocyanate Part A should not be stored in areas with fire suppression equipment that utilizes water.
3. Storage of containers coated with polyurea inside buildings shall be on such noncombustible surfaces as asphalt, concrete, or metal pallets.

1.2.2 Application (Spray)

1. The application of polyurea to the exterior of a structurally unsound container that is to be overpacked or a structurally unsound piece of equipment that must be overpacked cannot change the decision to overpack the material based solely on the polyurea. Specifically, polyurea can be applied to a structurally sound container just to prevent the spread of surface contamination and the container will not need to be placed into an overpack.
2. Any container in any condition may be sprayed with polyurea, but containers that are not placed in an overpack must exhibit sound structural integrity.
3. Any polyurea product may be used that has an ASTM E84 flame spread rating of less than 25 and a smoke developed index of less than 450.
4. The polyurea thickness shall not exceed the thickness used for the ASTM E84 test, ensuring the flame spread index is less than 25 for that product.
5. Facilities shall develop procedures that identify the appropriate PPE for operation of the spray equipment.
6. Facilities shall develop procedures that ensure container surfaces requiring patching shall use materials similar to those used in the original construction of the container. Any individual patched area (i.e., area of metallic duct tape) on metal containers shall not exceed 9 in^2, and tape patches cannot be more than 5% of the total container surface. Areas of metal containers requiring patching larger than 9 in^2 or exceeding 5% of the total container surface shall use a noncombustible patching material, and it shall be held in place by noncombustible mechanical means; i.e., no adhesives.
7. Any container that is considered vented before an application of polyurea shall have a vent path ensured after it is coated.

1.2.3 Onsite Transportation

1. Polyurea coating must be fully cured prior to offering those containers for transport.

2.0 POLYUREA AND APPLICATION

2.1 POLYUREA DESCRIPTION

Polyurea Development Association, the polyurea industry's trade association, has developed a "formal definition" to help suppliers, engineers, and contractors differentiate between real polyureas and other materials that "claim" to be polyureas. A polyurea coating/elastomer is that derived from the reaction product of an isocyanate component and a resin blend component. The isocyanate can be aromatic or aliphatic in nature. It can be monomer, polymer, or any variant reaction of isocyanates, quasi-prepolymer, or prepolymer. The prepolymer or quasi-prepolymer can be made of an amine-terminated polymer resin or a hydroxyl-terminated polymer resin. The resin blend must be made up of amine-terminated polymer resins and/or amine-terminated chain extenders. The amine-terminated polymer resins will not have any intentional hydroxyl moieties or functional groups. Any hydroxyls are the result of incomplete conversion to the amine-terminated polymer resins. The resin blend may also contain additives or other nonprimary components. These additives may contain hydroxyls, such as predispersed pigments in a polyol carrier. Normally, the resin blend will not contain a catalyst(s).

The InstaCote SE FR polyurea (Appendix B) is a spray-applied, aromatic, coating system. It is composed of a Part A material (isophorone diisocyanate and polyoxypropyleneamine) and a Part B material (diethyltoluendiamine, proprietary light stabilizer, proprietary polyetheramine, proprietary polyoxypropyleneamine, and carbon black). This material exhibits extreme toughness and elastomeric performance characteristics. The material can be applied to a variety of surfaces that are clean and dry. It has the ability to encapsulate areas of corrosion on a container, allowing normal handling while dramatically increasing its weather resistance for outside storage or reducing the risk of contamination spread. Also, after the polyurea application has cured, it is 100% solid, and no volatile organic compounds (VOC) are given off. The drying schedule of polyurea to the touch and tack free is about 45 seconds, light traffic is 2 hours, and full cure, to achieve the maximum rated physical properties, is approximately 24 hours.

Polyurea coatings and linings are commonly applied over concrete and steel for corrosion protection and abrasion resistance. They also have tremendous advantages over conventional materials for joint fill and caulk applications due to their fast set nature, high elongation, durability, and abrasion resistance characteristics. A partial listing of polyurea applications include pipe/pipeline coatings and linings, bridge coating, tank coatings, tank linings, roof coatings, waste water treatment linings, truck bed liners, water parks and playgrounds, railcar lining and track containment, and fuel storage and containment.

Polyureas have certain physical characteristics suitable for rapid process applications that have proven useful for coating applications including:

- Fast, consistent reactivity and cure, reducing the likelihood for pockets of unreacted material

- Moisture and temperature insensitivity during processing, ambient air and surface temperatures between -28.9 °C to 48.9 °C (-20 °F and 120 °F) with the maximum relative humidity of 80%, making the range of ambient humidity and temperatures favorable for use at Hanford

- Excellent physical properties/elastomeric qualities, making it extremely tough to reasonable impacts

- Very low water absorption qualities and hydrolytically stable, both of which provide good separation of environmental moisture from the applied substrate

- High thermal stability; maintains good physical properties over a wide temperature range (-40 °C to 177 °C [-40 °F to 350 °F])

- Auto-catalytic, no solvents; evaporation of organic solvents not required for curing

- High crack bridging; ability to cover small cracks and effectively maintain surface integrity over moving cracks

- Strong adhesion to a variety of surfaces.

2.1.1 InstaCote SE FR Isocyanate, Part A, and Resin, Part B

The MSDS for InstaCote SE FR isocyanate, Part A; resin, Part B; and cured product is located in Appendix B and is judged to be a reasonable example of polyurea technology. Therefore, it is only summarized in the following sections. Section VII of each MSDS specifies the "Precautions for Safe Handling and Use." The precautions of both parts are very similar. The following personnel safety provisions are for InstaCote SE FR and are presented as an example of the types of concerns applicable to polyurea components. Facility operating procedures provide controls, as appropriate, for the handling of the Parts A and B chemicals including the spray application. These controls do not extend to the cured plastic because the MSDS does not list any health hazards for the cured product.

1. The application equipment is positioned upwind of the application area.

2. Safety glasses or face shield is required during lifting or exercising relief valves.

3. Personnel who may be sensitive to isocyanates are not allowed to participate in the application of polyurea. Sensitivity is either self-identified or identified by a medical provider through a work restriction.

4. The application of polyurea requires personnel to be in varying levels of PPE depending upon the stage of the activity. The job hazard analysis identifies the hazards and controls including PPE for those working with the polyurea. The person applying the polyurea is required to wear chemically-impermeable clothing (i.e., Tyvek[3]), supplied air with a tight-fitting face piece, and nitrile gloves. Personnel located inside the support trailer are required to wear less restrictive PPE due to a lower risk of exposure. To ensure personnel do not enter the application area without required PPE, a boundary is established until spray applications have been completed. A manufacturer's limitation exists on use of the supplied air. It cannot be used below 0 °C (32 °F) to prevent freezing of the regulator.

5. GUSMER[4] (proportioning unit) operates at pressures up to 24,132 kPa (3500 psi). To avoid serious bodily injury from hydraulic injection of fluid, hydraulic connections or service hydraulic components are never opened without bleeding all pressures to near zero.

6. Standard industrial hygiene and safety controls are implemented for other hazards that may be present during the polyurea application activity. These, too, are addressed in the activity's job hazard analysis.

2.1.2 Storage of Polyurea Components and Cured Product

Appendix B has the MSDSs for the InstaCote SE FR Part A, Part B, and the cured product. Section III lists the Physical/Chemical Characteristics, Section IV describes the Fire and Explosion Hazard Data, and Section V describes the Reactivity Data. This information is presented as an example of polyurea technology. The application equipment and coating materials may be stored in a trailer to provide ease of movement between spraying locations; however, the trailer is not required for spray areas that are established primarily for the polyurea application. Table 2-1 summarizes pertinent physical and chemical characteristics with regards to the storage of the InstaCote SE FR Part A, Part B, and the cured product.

Given the information in the Table 2-1 the polyurea components have reactive characteristics that support separation from the chemicals listed above and specifically water. The isocyanate Part A should not be stored in areas with fire suppression equipment that utilizes water. The storage of polyurea coated containers must be separated from the potential for contact with concentrated, strong acids.

In testing of a similar InstaCote product, ML-2R Soft TR004 Blue, using BSS 7239-88, *Test Method of Toxic Gas Generation by Materials on Combustion* (see Appendix C), the predominant combustion products detected were carbon monoxide and oxides of nitrogen along with trace amounts of hydrogen chloride and hydrogen cyanide. Other products that could be present, but were not detected, are sulfur dioxide, hydrogen fluoride, ammonia, aldehydes, and keytones. These combustion products are consistent with those found in home appliances, sidings, insulation, trains, planes, and automobiles and are less toxic than what is typically found

[3] Tyvek is a registered trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.
[4] Gusmer-Decker Reaction Injection Molding (RIM) equipment is manufactured by GRACO OHIO Inc. a subsidiary of GRACO Inc.

in Hanford waste containers. In fighting a fire that involves a polyurea-coated container, fire fighters will use bunker gear, self-contained breathing apparatus with a full face mask, helmet, gloves, and boots. Additionally, Hanford personnel are trained to proceed to an upwind location or to evacuate during a fire.

Table 2-1. Physical Characteristics Pertinent to Storage.

	Part A	Part B	Cured product
Flash point	202 °C (396 °F) Cleveland Open Cup (C.O.C.).	>135 °C (>275 °F).	Not applicable.
Upper and lower explosive limits	Not determined.	Not established.	Not determined.
Fire-extinguishing media/methods	Use dry chemical, CO_2, foam. If only water is available, use a very large volume; reaction with water may be violent. Runoff water must be retained.	Use dry chemical, CO_2, foam, or water.	Use dry chemical, CO_2, foam, or water.
Special fire-fighting precautions	Full face shield, self-contained breathing apparatus with full protective gear.	None.	Full face shield, self-contained breathing apparatus with full protective gear.
Unusual fire/ explosive hazards	Isocyanate and water combined react to produce carbon dioxide.	None.	Carbon monoxide (CO) and oxides of nitrogen (NO_x) are the most predominant combustion products; however, trace amounts of HCl, HCN, HF, SO_2, NH_3, keytones, and aldehydes may also be produced.
Reactivity data/ materials to avoid	Product reacts violently with water, alcohol, amines, acids, and bases.	Do not mix with nitrites and may react violently with acids.	Concentrated strong acids.

Part A information from the MSDS # 064670 (Appendix B).
Part B information from the MSDS # 064671 (Appendix B).
Cured polyurea product information from the MSDS # 064672 (Appendix B).

The above physical characteristics pertinent to the storage of the InstaCote SE FR components are judged to be representative for the polyurea coating/elastomer. Any other polyurea product needs to have the manufacturer's data and MSDS reviewed and any special storage considerations implemented.

2.1.3 Polyurea Application

The application equipment includes the coating chemicals, a plural pump (system which has the ability to pump two chemicals in a specified ratio), and space for storage of the hose. A diesel generator and air compressor are also required. The plural pump contains heating elements that raise the temperature of the chemicals components to approximately 77 °C (170 °F). An air pump is installed in each of the two drums along with an air operated mixer in the Part A isocyanate drum. There are two hoses, generally 30.5-61 m (100-200 ft) in length, that are heat traced to maintain the 77 °C (170 °F) application temperature. The diesel generator powers the heating system, plural pump, hose heat tracing, and air compressor. The Parts A and B chemicals are air pumped from the drums to the plural pump, which is then pumped through the hoses. The two parts flow through the heat-traced hoses where they mix at a 1:1 ratio upon exit from the spray gun (impingement mixing).

The PPE required for the application of polyurea is the same as for the handling of the components as listed in Section 2.1.1, except the minimum respiratory protection for polyurea application for the sprayer will be an ambient air pump or bottled air. Table 2-2 shows the safe handling and use parameters for the InstaCote SE FR, which are reasonable for other polyurea applications. Consideration for the application of other polyurea products needs to be compared with the process description here and appropriately adjusted.

The cured product does not require specialized or unusual handling or use considerations. The primary concern with the application process is the respiratory tract irritation, which prompts the use of supplied air.

The successful adhesion to a surface by any product including polyurea, paint, urethanes, epoxies, etc., can be affected by the surface preparation. The polyurea coatings should be applied to a surface that is clean, dry, and in sound condition. Polyurea is not credited with providing structural strength for any container. Therefore, facility CMP procedures must establish the structural integrity and the need to overpack a container prior to applying a polyurea coating. However, the polyurea coating does not remove the ability to place a coated package into an overpack subsequent to the application of polyurea. CMPs that evaluate a package and conclude the container must be overpacked must not reverse the overpack decision based solely on the application of polyurea. However, polyurea may be utilized to prevent the spread of surface contamination on a sound container and that container may not need to be placed into an overpack because of the polyurea.

Table 2-2. Safe Handling and Use. (2 sheets total)

	Part A	Part B	Cured product
Work practices	May be used indoors or outdoors. Supplied air and protective clothing are used to prevent exposure when applying. The application site is separated from operating personnel.	May be used indoors or outdoors with adequate respiratory and/ or ventilation controls. Do not use in the presence of flames or sparks. Supplied air and protective clothing are used to prevent exposure when applying. The application site is separated from operating personnel.	None.
Ventilation	If vapors or mists are generated during application inside buildings, local exhaust ventilation is recommended. Ventilate area and avoid breathing vapors. Use supplied air respiratory protection during spraying and full protective clothing to clean large spills or spills in confined areas. Contain spill and prevent entry into sewers and waterways.	If routine indoor use is required, or in the presence of excess mist generation, local exhaust ventilation is recommended.	None.
Neutralization procedure	Use 0.2-0.5% liquid detergent mixed with 3-8% ammonium hydroxide or 5-10% sodium carbonate in water. Use 10 parts of solution for 1 part spill material. Allow 30 minutes to deactivate before placing spilled material into drums. Do not mix with any other waste material.	None.	None.

Table 2-2. Safe Handling and Use. (2 sheets total)

	Part A	Part B	Cured product
Waste disposal procedures	The cleanup of a spill of Part A is a hazardous waste in Washington State and must be disposed according to hazardous waste practices.	The cleanup of a spill of Part B is a hazardous waste in Washington State and must be disposed according to hazardous waste practices.	None.
Storage/handling procedures	Store product in a dry environment away from strong bases and oxidizers. Do not place in contact with copper metal, copper alloys, or zinc-coated metals. This product should not be stored in buildings with water fire suppression systems.	Store product in a dry environment away from strong acids and oxidizers.	Do not store near strong acids.

Part A information from the MSDS # 064670 (Appendix B).
Part B information from the MSDS # 064671 (Appendix B).
Cured polyurea product information from the MSDS # 064672 (Appendix B).

Polyurea can be placed over corrosion or rust areas on steel. Even if there is loose rust in small areas, the entire circumference of the drum can be sprayed. For preparation of FRP or plywood boxes, ensure the surface is clean, dry, and free of loose dirt as much as possible. Areas of wood or FRP boxes requiring patching shall use materials similar to those used in the original construction of the box or use a noncombustible patching material.

2.1.4 Environmental Effects of the Cured Product

A benefit of polyurea coatings is the protection it provides from environmental effects. Because containers can be protected from weather conditions, an evaluation of the impact on the polyurea over long-term environmental exposure is prudent. Polyurea technology has not been in use long enough to establish empirical data on the degradation over the long term, greater than 15 years. However, an investigation into the estimated life expectancy resulted in an example of two large outdoor projects that included steel bridges and concrete exposed to sea water. The life of the polyurea coating under these environmental conditions was estimated at 75-100 years. The following sections address the various Hanford weather conditions and the expected influence on the integrity of polyurea coatings.

2.1.4.1 Temperature. Yearly and daily temperature cycling from the highs to lows has an effect on building materials. The temperature range that polyurea can be expected to maintain its physical properties is -40 °C to 177 °C (-40 °F to 350 °F). Polyurea technology is about 20 years old with the long-term quantitative environmental performance information not readily available. Polyurea was originally developed for use in the automotive industry and is still in use today because of the ability of the material to withstand thermal cycling and seasonal variations. The utilization of polyurea on bridges by the U.S. Department of Transportation (DOT), roof covering, and other outdoor uses qualitatively defends the materials' resistances to environmental temperature cycling. The literature search for outside applications of polyurea resulted in observations that after 15 years of exposure, polyurea experiences minimal effect on the elastomer (slight reduction of gloss) and no effect at temperatures as low as -54 °C (-65 °F). The expected period of outside storage of containers on the Hanford site can be estimated at periods less than the expected integrity of the polyurea applied to a structurally sound waste container.

2.1.4.2 Moisture. Another environmental condition that affects building materials is moisture from rain, snow, and fog. The moisture vapor transmission of InstaCote SE FR is 0.025 perms at 30 mils. The perm is a unit of measurement for the ability of a material to retard the diffusion of water vapor at 73.4 °F (23 °C). This is half that of saturated and coated rolled roofing, which has a permeance of 0.05. Note that the polyurea coating will be applied at a thickness of 80-120 mils with the permeance being directly proportional to the thickness. This results in superiority over saturated and coated rolled roofing of almost eight times. The InstaCote SE FR is the product of choice for Hanford and may be applied up to a thickness of 516 mils consistent with the thickness used for the flame spread rating. It is judged that polyurea coatings significantly retard the diffusion of environmental moisture, providing the weatherization protection for container surfaces in extended storage and preserving the integrity of containers.

2.1.4.3 Ultraviolet (UV). Quantitative data on the long-term effects of UV radiation on polyurea coatings is not available. UV is a component of the cumulative effect of environmental exposure. The utilization of polyurea coatings on outside applications over the last 15 years resulted in minimal effect on the elastomer with only a slight graying and loss of gloss. The utilization of polyurea on bridges, roof covering, and other outdoor uses qualitatively defends the material's resistance to environmental pressures including exposure to UV radiation. The expected period of outside storage for waste containers on the Hanford Site can be estimated at periods less than any detrimental reduction in physical characteristics of the polyurea applied to the exterior of a structurally sound waste container.

2.1.4.4 Radiation. The University of Michigan performed radiation testing on an InstaCote sample to a total dose of 10^8 Rad (*Irradiation Study of InstaCote Samples* [UMich 1995]). Effects noted were that the modulus of elasticity and hardness were insensitive to the radiation dose. Material ductility, tensile strength, and tear strength did not significantly decrease at a dose of 5×10^7 Rad (which is equivalent to approximately 280 R/h for 20 years).

RPP-7806, *Project W-314 Polyurea Special Protective Coating (SPC) Test Report Chemical Compatibility & Physical Characteristics Testing*, prepared for CH2M HILL Hanford Group, Inc., by the Los Alamos Technical Associates, Inc., describes radiation testing on the

Envirolastic 425 polyurea (Appendix A). The coupons were irradiated with 1.0×10^7R, and the only effect noted was a slight change in color from the color gray to a slightly darker olive-tinted gray. The average pull-off strength of four preparation groups resulted in the unirradiated samples being between the average pull-off strength of the irradiated samples. In another preparation group the unirradiated sample had a slightly higher pull-off strength than that of the two irradiated samples. Based on the data the conclusion is that 1.0×10^7R gamma radiation does not affect the adhesive strength of polyurea. Because the adhesive strength depends largely on the other physical characteristics, it is judged that radiation will not significantly impact the polyurea coatings.

3.0 ONSITE TRANSPORTATION

The transportation of all packages on the Hanford Site must comply with the transportation safety-basis documents for that packaging system. Compliance with the requirements, limitations, or controls described in the safety basis for a package system will not be relaxed or modified because of the application of polyurea. The transportation of waste packages coated with polyurea does not credit the coating with enhancing the structural, thermal, containment, shielding, criticality, or gas-generating posture of a package. Facility CMPs must determine if a container requires an overpack prior to the polyurea application recognizing that such circumstances as newly discovered surface contamination or loss of integrity may require a previously unoverpacked package to subsequently require overpacking. Also, a structurally sound container that has surface contamination may be placed into an overpack to prevent the spread of contamination. A benefit of polyurea is that an application that encapsulates the surface contamination may eliminate the need to place the container into an overpack, thus reversing the decision to overpack. The emphasis is placed on the need to overpack a container based on the integrity of the structure since polyurea is not credited to enhance the sturdiness of a container.

The Hanford onsite transportation of the resin Part B and the cured product is nonregulated. The cleanup of a spill of Part A and/or Part B is a hazardous waste in Washington State and must be disposed according to hazardous waste practices The isocyanate Part A will be transported as DOT Hazard Class 9, other regulated substance, liquid n.o.s. identification number UN3082.

3.1 PAYLOAD DESCRIPTION

Polyurea is a coating sprayed on the outside of a container to minimize the potential for contamination spread and provide protection from the environment. It is expected that the benefits of the coating will be realized primarily for packages that are being retrieved from the low-level burial grounds; however, the scope of this report includes any packages located on the Hanford Site that require transportation to or from any facility on the Hanford Site. All of the normal and accident conditions evaluated in these sections are completed with the cured polyurea product.

Polyurea cannot add to, subtract from, or by its use redistribute the radioactive waste material that is placed inside a container. Also, application of polyurea cannot cause the container to exceed its gross weight limit. However, the possibility that a coated package will require overpacking subsequent to the application of polyurea cannot be dismissed. Facility CMPs must evaluate each package and conclude whether or not a container must be overpacked. The application of polyurea will not reverse the decision to overpack a container, unless the polyurea is used to prevent the spread of surface contamination on a structurally sound container.

The flame spread and smoke density testing is evaluated with respect to the transportation accident analysis in DOE/RL-2001-36. The collision with fire accident scenario for transportation assumes the containers, payload, and material at risk are fully engulfed in the fire. The damage ratio, airborne release fraction, and respirable fraction identified in DOE/RL-2001-36, Appendix G, Tables 2a and 2b, are consistent with the definition of "packaged waste" in HNF-8739, *Hanford Safety Analysis and Risk Assessment Handbook (SARAH)*, Table 3.5. HNF-8739 describes this material as generally combustible contaminated waste in plastic bags or taped plastic bags or in pails, drums, and waste boxes.

The ASTM E84 flame spread test data for the polyurea Envirolastic AR 425 and InstaCote SE FR indicates both materials are Class A (or 1) building material by the National Fire Protection Association; i.e., both have a flame spread rating of less than 25 and smoke-developed index of less than 450. These products were tested at different thicknesses: 20.0 mils (0.02 in.) for the Envirolastic AR 425 and 516 mils (0.516 in.) for InstaCote SE FR. The facility shall implement controls to ensure the polyurea product used on the Hanford Site shall have a flame spread rating of less than 25 and will not be applied at a thickness greater than the thickness used for the flame spread ASTM E84 test.

The smoke density caused by the burning plastics, tape, wood, and other cellulosic and synthetic materials will not be significantly increased by the presence of polyurea, which, for the purposes of gas generation, is estimated to be approximately 9% of the total mass of a package (see Section 3.9). The smoke density of the InstaCote SE FR is determined to be 115 (Appendix C) as compared to red oak flooring that has a rating of 100. Because the polyurea is fire retardant, any exposure to a fire will last only as long as the combustibles in or near a container continue to burn. Because the smoke density is approximately the same as the red oak, the contribution to smoke density from the polyurea is not judged to be significant. A fire involving cured polyurea can be extinguished utilizing standard fire suppression materials, methods, and practices, such as a full face shield or self-contained breathing apparatus, water, foam, dry chemicals, or carbon dioxide. The inhalation of smoke and dust particles is a standard hazard associated with extinguishing fires.

3.2 COMPLIANCE WITH DOE/RL-2001-36 PACKAGING STANDARDS

The transportation of all containers on the Hanford Site must comply with the transportation safety-basis documents for that packaging system. Compliance with the requirements, limitations, or controls described in the safety basis for a package must not be relaxed or modified because of the application of polyurea. The inspection criteria described in facility procedures and work packages that ensure compliance with CMPs and transportation safety-basis documentation will dictate the need to overpack a package. The addition of polyurea does not impact the compliance with normal conditions of transport (NCT) under U.S. Department of Energy (DOE)-approved authorizations.

3.2.1 Statement of Compliance to DOE/RL-2001-36 Packaging Standards

This technical report evaluates the benefits, concerns, and limitations of using polyurea compounds on the Hanford Site including the transportation of waste containers; e.g., drums, wooden boxes, FRP or metal boxes, tanks, casks, or other containers. One objective is to demonstrate that containers with a properly applied external application of polyurea coating can be transported between facilities on the Hanford Site with a level of onsite safety equivalent to that achieved offsite. The use of polyurea does not compromise the parameters, requirements, limitations, and controls described in DOE/RL-2001-36 and the U.S. Department of Energy, Richland Operations Office (RL)-approved package-specific authorizations; e.g. package-specific safety documents (PSSD), one-time requests for shipment. DOE/RL-2001-36, Section 6.1.1.3, provides that when full compliance with U.S. Department of Transportation (DOT) regulations or DOT-equivalent packaging for radioactive materials cannot be achieved for onsite shipments because of technical or economic conditions, a risk-based method for demonstrating an acceptable "equivalent" level of safety will be implemented, i.e., "risk based." Requirements for risk based packages are developed to result in a package that under Site conditions will produce radiological and toxicological risk equivalent to an offsite package subjected to regulatory-established tests and conditions.

Polyurea applied to a package is not credited with enhancing the structural, thermal, containment, shielding, criticality, or gas generating posture of a package. Compliance with the requirements, limitations, or controls described in the safety basis for a package must not be relaxed or modified because of the application of polyurea. The inspection criteria that ensure compliance with CMPs and transportation safety basis documentation are described in facility/project procedures and work packages.

3.3 SUMMARY OF TRANSPORTATION EVALUATION

Utilizing the parameters, requirements, limitations, and controls described in DOE/RL-2001-36 and the RL-approved package-specific authorizations (e.g., PSSDs, one-time requests for shipment, and Special Packaging Authorizations), this evaluation concludes that polyurea coatings on containers does not impose an undue hazard for normal and accident conditions. HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Section 2.13.2, states, "Outer containers shall be in good condition, with no visible cracks, holes, dents, bulges, pit or scale corrosion, or other damage that could compromise container integrity (WAC 173-303-630). Minor external surface rust that can be sanded or brushed off will be acceptable. Containers having some pit or scale corrosion could be acceptable for storage provided the integrity of the container is confirmed. Polyurea coated containers must have a Flame Spread rating of 25 or less for acceptance into CWC." The Waste Receiving and Processing Facility and T Plant have similar requirements for exterior coatings, and it is expected that other Hanford facilities will have similar restrictions. The facilities shall ensure that the polyurea application thickness does not exceed the thickness used for the ASTM E84 flame spread test. Facility operating procedures are required to identify criteria by which the "good condition" of containers is determined, and if not in "good condition," the containers are overpacked in order to ensure the outer container is in "good condition."

The application of polyurea to the exterior of a package that is to be overpacked or a piece of equipment that must be overpacked cannot change the decision to overpack the waste material. The polyurea application to a package is expected to mitigate the possibility of spreading contamination during storage, handling, or processing and also provide protection from environmental elements. Containment/confinement requirements applicable under DOE/RL-2001-36/PSSDs must be met as specified and in a manner that is completely independent of the presence of the polyurea. Polyurea that fully encapsulates surface contamination resulting in compliance with surface contamination requirements allows the container to be handled, stored, and transported as a sound container without surface contamination.

The coating may be used on such waste packages as waste drums, metal boxes, plywood boxes, FRP boxes, tanks, casks, concrete, or other containers. Polyurea applied to a package is not credited with enhancing the structural, thermal, containment/confinement, shielding, criticality, or gas-generating posture of a package. Packages that have a polyurea coating on the exterior can be placed into an overpack or other package and will not affect the safe transportation of that package provided all limits and controls established for that package in the RL-approved authorizations are complied with.

Polyurea cannot add to, subtract from, or by its use redistribute the radioactive waste material that is placed inside a package. A consideration for the use of polyurea would be gross weight limits for both the container and conveyance, but the gross weight limits are not derived from, modified, or revised because of the polyurea coating. Even though one of the intended uses of the polyurea coating is to minimize the spread of radioactive contamination, this evaluation cannot ignore the possibility that a coated package will require overpacking subsequent to the application of polyurea. For example, surface contamination from a source external to the coated package cannot be ruled out. Facility CMPs must determine if a container needs to be overpacked prior to the polyurea application, and the polyurea coating must not affect the ability to place a package or piece of equipment into an overpack.

The collision-with-fire accident scenario for transportation assumes the containers, payload, and material at risk are fully engulfed in the fire. The packaged waste material described in HNF-8739 (SARAH) is generally combustible contaminated waste in plastic bags or taped plastic bags or in pails, drums, and waste boxes. The propagation of the fire will be caused primarily by the combustible waste materials because the flame spread described in Appendix C for InstaCote SE FR supports conclusions that the polyurea is a Class A building material with relatively low fire propagation potential. Also, the smoke density (Appendix C) of the fire is primarily caused by the burning plastics, tape, wood, and other cellulosic materials and will not be significantly increased by the presence of polyurea.

The only specific transportation controls unique to the polyurea coating are that (1) it must be fully cured in accordance with the manufacturers' recommendations prior to being subjected to transport and (2) marking and labeling of the coated container must be placed on the outside of the container after coating. No other requirements, limitations, and controls described in the RL-approved package-specific authorizations (e.g., PSSDs, one-time requests for shipment) are impacted in any way by the application of polyurea.

3.4 STRUCTURAL

Acceptable performance of packages containing radioactive waste to maintain containment and structural integrity under NCT in accordance with DOE/RL-2001-36, Section 6.1.1.3, is demonstrated by a combination of physical testing and engineering analysis. As stated in DOE/RL-2001-36, when a DOT-equivalent packaging for radioactive materials cannot be achieved for onsite Hanford shipments, a risk-based method (i.e., engineering analysis) may be implemented.

The authorization to transport a package on the Hanford Site is established with the approval of safety-basis documentation for the specific package. The safety-basis documentation includes the analysis of the structural integrity-imposed stresses during normal and accident conditions for each package. This evaluation does not credit the polyurea coating with contributing to the integrity of any container; it is only credited with contamination control. The weight of the container due to the polyurea coating will not exceed the limitation for the container or conveyance, as defined in the safety-basis documentation for that container, because the gross weight limits are not derived from, modified, or revised because of the polyurea coating.

The concern that polyurea may become brittle for reasons other than thermal shock has been investigated. The isolated legal actions in the polyurea industry are related to an improper application process. Specifically, cracking has occurred when the polymer system is applied off-ratio; i.e., significant offset of the 1:1 Part A-to-Part B volume or mix ratio. This issue is compounded by improper heating (too low) of the system when being processed. This leads to a very hard segment that is brittle in nature. The proper spray application for the InstaCote SE FR is ensured when the application pressures of Parts A and B are within 1379-2068 kPa (200-300 psi). Other polyurea manufacturers may have different application specifications that will be followed.

Another cause of embrittlement was linked to application over unsupported substrates, such as a geotextile fabric, resulting in cracking of the polymer. Polyurea technology systems are designed to be applied to solid substrates, such as concrete, metal, or wood. Cracking is due primarily to the cure shrinkage forces. It has been observed that outdoor use of very thin layers of aromatic-based formulations of polyurea can result in UV degradation leading to cracking and severe oxidation. This degradation is accelerated in formulations with little to no pigment and none of the required performance additives. It has been recommended that a minimum of 25–30 mils be used for outdoor work.

3.5 THERMAL

The purpose of the thermal evaluation is to determine the performance of packages under NCT and hypothetical accident conditions. The contents of the package are various radioactive materials with a total decay heat load that varies with the source term and package as evaluated in the RL authorizations for the specific package.

DOE/RL-2001-36, Section 6.5.2.4.4, "Thermal Limitations," states that (a) Heat generated within the package by the radioactive contents will not, during conditions normally incident to transport, affect the integrity of the package; and (b) Temperature of the accessible external surfaces of the loaded package will not, assuming still air in the shade at an ambient temperature of 38 °C (100 °F), exceed:

1. 50 °C (122 °F) in other than an exclusive-use shipment; or
2. 85 °C (185 °F) in an exclusive-use shipment.

DOE/RL-2001-36, Section B.3.8.1, states:

> "Based on climatological data reported from 1912 to 1980 in WHC-SD-TP-RPT-004, *Environmental Conditions for On-Site Hazardous Materials Packages*, the highest recorded temperature on the Hanford Site is 46 °C (115 °F). Consequently, site-specific determination of maximum allowable package external temperature is based on a more severe condition than for the regulations."

The polyurea spray systems must be processed through high pressure, high temperature impingement mix type equipment in order to achieve the optimum atomization and qualities for a coating. The polyurea material needs to be between 66 °C (150 °F) and 77 °C (170 °F) (Appendix A) during the application. However, the affect of the application temperature on the "integrity of the package" with regard to the common gasket materials warrants consideration. Gasket materials are generally synthetic rubbers that have an operating range between -40 °C to 125 °C (-40 °F to 257 °F) and are used in the various Hanford containers; e.g., drums, plywood boxes, FRP boxes, concrete boxes, and metal boxes. A common gasket material used at Hanford is the nitrile (Buna N) rubber that has an operating service temperature range of -54 °C to 135 °C (-65 °F to 275 °F) (ORD 5700A/US, *Parker O-Ring Handbook*). Plywood and FRP boxes are nailed or screwed together, and their joints and tops may be glued with Weldwood[5] Plastic Resin Glue. The top-to-body joints of concrete boxes are caulked. Caulking is typically polymerized siloxanes (silicone), which is stable at high temperatures (-40 °C to 232 °C [-40 °F to 450 °F]). It is used as a basic sealant against water and air penetration, but is not credited with providing containment, confinement, or structural integrity. The polyurea application temperatures will not impact the functionality of these silicone sealants or the Buna N gasket materials. The polyurea

[5] Weldwood is a registered trademark of the DAP Brands Company, Medina, Ohio.

applied to the exterior of a structurally sound container that will not be overpacked must not exceed the temperatures stated above.

HNF-2209, *Safety Analysis Report for Packaging (Onsite) Steel Drum*, Part B, describes the thermal evaluation for 208 L (55-gal) and 322 L (85-gal) drums. The thermal evaluation for Standard Waste Boxes (SWB) made from carbon steel is described in HNF-SD-TP-SARP-004, *Safety Analysis Report for Packaging (Onsite) Standard Waste Box*. Table 3-1 shows the results of these evaluations.

Table 3-1. Results of the Thermal Evaluations in HNF-2209 and HNF-SD-TD-SARP-004.

Package	External temperature in the shade	External temperature under worst case solar insolation
208 L (55-gal) (12 W)	47 °C (116 °F)	63 °C (145 °F)
322 L (85-gal) (12 W)	46.8 °C (116.2 °F)	Average surface 80.5 °C (177 °F) Peak temperature on the lid 120 °C (248 °F)
Standard Waste Box (40 W)	63 °C (145 °F)	63 °C (145 °F)

HNF-2209, 2006, *Safety Analysis Report for Packaging (Onsite) Steel Drum*, Rev. 1-B, Fluor Hanford, Inc., Richland Washington.

HNF-SD-TP-SARP-004, 2005, *Safety Analysis Report for Packaging (Onsite) Standard Waste Box*, Rev. 2, Fluor Hanford, Inc., Richland, Washington.

The thermal evaluations are evaluated at steady-state thermal conditions, so all of the heat generated or absorbed by the drum or box is lost to the environment, resulting in the highest surface temperature. The heat balance can be described as:

$$Q_{decay} + Q_{solar} - Q_{convection} - Q_{radiation} = 0$$

The heat generation terms are the $Q_{decay} + Q_{solar}$. The 12-hour solar insolation is given as 0 for packages located in the shade, and DOE/RL-2001-36, Table 6-4, shows 12-hour solar insolation for horizontal and curved surfaces. Neither of these heat-generating terms will be affected by the application of polyurea. The heat rejected from the packages will be via convection and radiation only. Heat transfer by natural convection can be described by the following equation:

$$Q_{convection} = h_c A_s (T_s - T_\infty)$$

where:

h_c = Convection heat transfer coefficient, W/m^2-K
A_s = Surface area, m^2
T_s = Surface Temperature, K
T_∞ = Ambient temperature, K.

Heat transfer by radiation can be described by the following equation:

$$Q_{radiation} = \sigma \varepsilon F_{12} A_r (T_s^4 - T_\infty^4)$$

where:

σ = Stefan-Boltzmann constant, 5.67 x 10^{-8} W/m^2-K^4
ε = Thermal emissivity of the surface, dimensionless (WHC-SD-TP-RPT-005, *Thermal Analysis Methods for Safety Analysis Reports for Packaging)*
F_{12} = Gray body view factor, dimensionless, 1 for large surroundings (WHC-SD-TP-RPT-005)
A_r = Effective radiative surface area, m^2.

The Stefan-Boltzmann constant is a physical constant of proportionality in the Stefan-Boltzmann law, which is defined as the total energy radiated per unit surface area of a black body in unit time is proportional to the fourth power of the thermodynamic temperature. The emissivity of a material is the ratio of energy radiated by the material to energy radiated by a black body at the same temperature. It is a measure of a material's ability to absorb and radiate energy. A true black body would have an $\varepsilon = 1$ while any real object would have $\varepsilon < 1$. The application of polyurea to the drums and boxes does not affect the temperatures, convection heat transfer coefficient, Stefan-Boltzmann constant, or the Gray body view factor. Therefore, the three heat transfer terms, assuming all the heat generated and absorbed is lost to the environment, that are affected by an application of polyurea that fully coats the package are as follows:

A_s = Surface area, m^2
A_r = effective radiative surface area
ε = Thermal emissivity of the surface, dimensionless (WHC-SD-TP-RPT-005).

For packages that are fully coated with a 500 mils (0.5 in.) of polyurea, the surface area available for convective heat transfer is larger than the original calculation. The thermal emissivity used in HNF-2209 for the drums is 0.85 for enameled paints on steel at 37.8 °C (100 °F). The thermal the emissivity used in HNF-SD-TP-SARP-004 for the SWB is 0.9, which is referenced to WHC-SD-TP-SARP-006, *Safety Analysis Report for Packaging (Onsite) 85-Gallon Retrieval Drum*, which is for zinc-based paint. The physical properties of polyurea are very similar to high-density polyethylene, so the emissivity of high-density polyethylene is 0.90 at 37.8 °C (100 °F) (WHC-SD-TP-RPT-005) and is judged to be representative of polyurea. Because the heat generated is equal to the heat transmitted to the environment, as the surface area and emissivity of a package are increased, the surface temperature is decreased. The larger surface area, created by the application of polyurea, increases the natural convection at steady-state conditions and ultimately decreases the surface temperature. The conclusion of this thermal evaluation is that the surface temperature of any package previously determined in DOE-approved transportation safety-basis documents will bound the surface temperature of packages that are fully coated with polyurea. Thus, packages with only partially covered surface areas will experience a surface temperature similar to the previously evaluated DOE-approved safety-basis documents. These conclusions are supported for any thickness of polyurea, so controls on thickness are not required for the thermal analysis. The application of polyurea to a waste container does not have any negative thermal effects, but could enhance the thermal properties. This potential enhancement is not credited.

Section 3.4 addresses embrittlement caused by improper formulations, lack of a substrate, or too thin of application. DOE/RL-2001-36, Section B.3.3, "Brittle Fracture Acceptable Performance Criteria," states, "For package containment boundaries and critical components that are constructed from ferritic steels, low temperature brittle fracture of the materials needs to be addressed in a manner similar to certified Type B packages." Properly applied polyurea at the recommended thickness provides some environmental protection, and the container substrate provides the structural integrity. The InstaCote SE FR has very stable physical properties from -40 °C to 177 °C (-40 °F to 350 °F), so it is resistant to environmental pressures and is not expected to crack or spall within the temperature range. It should help reduce the potential for contamination spread, and because it is not ferritic steel, it is not credited with being a critical component. Therefore, brittle fracture is not evaluated further.

3.6 CONTAINMENT

The transportation safety basis that documents the requirements, limits, and controls of risk-based packages used on the Hanford Site address the frequencies and radiological dose consequences of analyzed accidents to establish the risk of using a packaging system. The accident rate used for the Hanford Site in DOE/RL-2001-36 is 2.2×10^{-7} accidents per vehicle-km (3.5×10^{-7} accidents/vehicle-mi).

Polyurea coating on a package being transported cannot impact any of the reasons used in establishing the accident rate. The accident frequency used in the transportation safety-basis documents for packaging systems is not changed by the use of polyurea.

The radiological dose consequences of postulated accident scenarios are described in DOE/RL-2001-36, Appendix G, Section G.1.5, "Dose Consequence Evaluation." The DOE/RL-2001-36, Appendix G, Section G.2, describes the analysis of three accident types: collision, collision with fire, and hydrogen deflagration. The derivation of dose consequences for these accidents depends largely on the source term of the payload, which is not changed by polyurea. Appendix G, Tables 2a and 2b, list the specific dose consequences of the above-mentioned accidents in the 100/200 Areas and the 300/400 Areas. Because the polyurea coating is not credited with any structural integrity, all the release fractions and damage ratios will remain unchanged. Also, as noted in Section 3.1 of this report, polyurea cannot add to, subtract from, or by its use redistribute the radioactive waste material that is placed inside a package. Therefore, the dose consequence analysis that assumes the entire quantity of material at risk is exposed to the accident conditions is not changed by the use of polyurea.

3.7 SHIELDING

The radioactive constituents of packages include a wide variety of radionuclides with the shielding consideration limiting the quantity by the radiological dose rate to the exterior of a package. The polyurea on the exterior of a package may provide some shielding; however, it is not credited for its shielding qualities. Envirolastic AR 425, Appendix A, can be applied at thicknesses of 30-250 mils (0.03–0.25 in.) or greater. InstaCote SE FR surface-burning characteristics, Appendix C, was tested at a thickness of 516 mils (0.516 in.), and the MSDS for the cured product does not identify a minimum or maximum thickness. Alternate thicknesses may be used provided an ASTM E84 flame spread test for the specific material and application is performed and the resultant flame spread rating is 25 or less. Due to the variability of the payload, the shielding evaluation estimates the maximum quantity of certain nuclides that may be transported in a single package based on a surface dose rate. Accordingly, the shipper must verify that the dose rate limits are met prior to transport. Because (1) the application of polyurea does not add to, subtract from, or redistribute the radioactive payload and (2) the coating of polyurea is not credited with reducing the dose rate, the surface dose rate limits established in the RL-approved safety-basis documentation for each package will be applied in accordance with DOE/RL-2001-36.

3.8 CRITICALITY

Safety-basis documentation that establishes the approval for the transportation of packages includes a criticality analysis for NCT as well as hypothetical accident conditions. DOE/RL-2001-36, Appendix D, Administrative Control D.5.3., "Nuclear Criticality Safety," requires that the maximum k_{eff} for all packages subject to DOE/RL-2001-36 is 0.95 including allowances for bias and uncertainty to provide an adequate margin of safety for transportation activities onsite.

The criticality evaluation documented in HNF-2209 indicates that because the isotopic distribution of the fissile material or the H/X ratio is not defined, the worst case is assumed (^{239}Pu in polyethylene). The conservative assumptions include drum contents of 50 vol% polyethylene with an optimum H/Pu ratio and full water reflection or infinite arrays. During normal transfer conditions under multiple variations of assumptions, the highest k_{eff} is calculated to be 0.6091 (HNF-2209, Table B11-8). The accident-condition calculations (HNF-2209, Table B11-9) describe k_{eff} that approaches or exceeds the limits for the infinite arrays. The finite array calculation for 19 drums 3 tiers high during accident conditions under multiple assumptions of configuration results in the k_{eff} that does not exceed 0.824.

The criticality evaluation documented in HNF-SD-TP-SARP-004 for the SWB is completed with various densities of polyethylene water mixtures. Four cases in HNF-SD-TP-SARP-004, Table B6-4, compare the k_{eff} with varying densities for the 60 vol% polyethylene/40 vol% water mixture outside the sphere and modeled inside the SWB that is reflected. The k_{eff} of 0.9331 is within the statistical uncertainties as the single package. This demonstrates that the SWBs in the array are neutronically isolated from one another with very little neutron communication between the boxes even with the maximum density of polyethylene/water. The analysis of the single-package SWB under accident conditions is identical to the normal conditions; i.e., the moderator was assumed to be even more effective than water with the combination of polyethylene and water in the spherical mix with plutonium oxide. The spherical assumption is the most reactive possible. The conservative accident conditions assume the packages are stacked together in an arrangement with close full reflection on all sides of the array by water and with optimum interspersed hydrogenous moderation. These conditions are the same as those for the array calculations under normal conditions. Hence, an additional accident-condition array analysis is not needed. The normal-condition calculations were made under the constraint that the SWB shipment can only be one tier high.

The amount of fissile material in the shipment available for release must remain subcritical under the worst conditions. The fissile material quantity or distribution within a package is not changed with an application of polyurea to the outside of a package. The addition of polyurea to the exterior of drums and boxes as a reflector and moderator is bounded by the assumptions in the analysis of fully reflected and reactive moderator configurations outside the package during normal and accident conditions. The polyurea cannot augment the most reactive conditions of moderation and reflection of neutrons assumed in the analysis. Therefore, the affect of polyurea on criticality safety is bounded by the existing analysis because the calculations are performed with conservative assumptions.

3.9 GAS GENERATION

The accumulation of flammable gas (e.g., hydrogen, low-flash point hydrocarbons, VOCs) in containers has the potential to occur from radiolytic decomposition of hydrogenous waste, organic waste, or low-flash point mixed waste or from chemical reaction of incompatible waste forms in conjunction with the failure or absence of vents in the containers. Radiolytic decomposition occurs due to the interaction of the radioactive material (e.g., alpha emitters) with water or organic material in the containers and generates hydrogen. In the absence or failure of vents in the containers, the flammable gases accumulate to the point where a deflagration potential exists; i.e., the lower flammability limit is exceeded. The rate of gas generation depends on several factors including radionuclide type and radioactivity, organic or hydrogenous material matrix, distribution of radionuclides in the matrix and within the container, and container corrosion. Because much of the waste at Hanford involves organic material contaminated with alpha emitters (transuranic [TRU] waste) inside the container and potentially as surface contamination fixed in place with the polyurea, the bounding scenario assumes hydrogen resulting from radiolytic decomposition of the polyurea caused by gamma radiation is the flammable gas of concern.

DOE/RL-2001-36, Section 6.5.2.6.15, "Flammable Gas Generation," states:

> "This section defines the requirements to demonstrate acceptable performance for onsite packaging in which the concentration of flammable gases within the package void volume has the potential to exceed one–half the Lower Explosive Limit (LEL). For Hydrogen gas, the value is 5 vol%. The requirements of this section do not apply to packages that have no flammable gas generation potential."

Transportation packages used on the Hanford Site are used to ship a wide variety of materials that can generate flammable gases from radiolysis, chemical or biological reactions, or the evaporation of organic compounds. HNF-EP-0063, Section 2.11.4, "Gas Generation," states:

> "When low-level waste is packaged, vents or other measures shall be provided if the potential exists for pressurizing or generating flammable or explosive concentrations of gases within the waste container (DOE M 435.1-1, Chapter IV, L.1.b). Unless otherwise specified by the WSD Project acceptance organization, a minimum five-year time value shall be used to demonstrate compliance when performing gas generation calculations for low-level waste going directly to disposal.
>
> When a container of newly generated transuranic waste is packaged, vents or other mechanisms shall be provided at the time the waste is packaged to prevent pressurization of the container or generation of flammable or explosive concentrations of gases. Containers of currently stored waste shall meet this requirement as soon as practical unless analyses demonstrate that the waste can otherwise be managed safely (DOE M 435.1-1, Chapter III, L.1.b)."

Therefore, recently filled waste packages of either low-level or TRU waste will have a vent or other mechanisms to prevent pressurization or the accumulation of flammable or explosive gases. When vents are installed, HNF-EP-0063, Section 2.11.4, requires:

> "...a certificate of conformance shall be provided stating the vent model number that has been installed on the waste container and that the waste packaging meets the requirements..."

The installed vent for the control of hydrogen from radiolytic or biological decomposition must be approved and listed in HNF-EP-0063, Appendix H, or an approved alternative. The generators of packaged waste are responsible for demonstrating that there is no potential to generate a flammable gas or that the vent mechanism is adequate to ensure that any combination of flammable gases generated since the package was sealed will remain below the flammable atmosphere.

Polyurea applied to the exterior of a retrieved or recently filled waste package does not impact the contents inside the package with regards to the coating's contribution to the generation of flammable gases. Any container that is vented must not have the vent path blocked after a polyurea coating is applied, so the vented status of a container cannot be impacted by a coating of polyurea. Other facilities should implement controls similar to HNF-14741, *Master Documented Safety Analysis (MSDA) for the Solid Waste Operations Complex (SWOC)*, that requires:

> "Any container that is considered vented shall have a vent path ensured after it is coated."

HNF-15280, *Technical Safety Requirements (TSR) for the Solid Waste Operations Complex (SWOC)*, Specific Administrative Control 5.6.1, requires:

> "The abatement period ends when the flammable gas hazard is abated (hydrogen concentration is determined to be less than 5% and other headspace gases are determined to be non-flammable)."

Also, Specific Administrative Control 5.6.1 requires:

> "Newly vented containers cannot be moved, other than to a staging area or for re-sampling, or processed until the flammable gas hazard(s) has been determined to be abated (less than 5% hydrogen and less than flammable levels for other flammable gases)."

Generally, but not always, surface contamination indicates that a penetration exists and flammable gases are automatically vented even while in storage. Some surface contamination is caused by external sources. Waste containers currently being stored or retrieved may not have a vent mechanism installed by the waste generator. The need to sample, process, or vent some of these containers may require the movement of the unvented package. HNF-20961, *Evaluation of Drums Suspected To Contain Greater Than 5% Hydrogen*, and HNF-22145, *One-Time Request for Shipment of Retrieval Packages in IP-1 Overpack*, describe administrative and engineered controls to be used to help mitigate the hazards of shipping unvented and vented drums having the potential for greater than 15% hydrogen. Compliance with the requirements, limitations, or controls described in these safety-basis documents for a package system will not be relaxed or modified because of the application of polyurea.

The autoignition temperature is the minimum temperature required to initiate self-sustained combustion in a combustible fuel mixture in the absence of a source of ignition. In other words, the fuel is heated until it bursts into flames.

Each fuel has a unique autoignition temperature. For hydrogen the autoignition temperature is at 585 °C (1085 °F). HNF-25634, *Potential for a Volatile Organic Compound (VOC) Deflagration in a TRU Drum*, Table 13, provides a list of the minimum autoignition temperatures of the VOCs of concern. The lowest autoignition temperature is for carbon disulfide at 90 °C (194 °F) with most of the VOCs in the 427 °C to 482 °C (800 °F to 900 °F) range. This makes it difficult to ignite a hydrogen/VOC/air mixture on the basis of heat alone without some additional ignition source. Because polyurea is applied at 77 °C (170 °F), the autoignition temperature for hydrogen or the VOCs is not reached as a result of the application of polyurea alone.

A review of drum fire/deflagration events throughout the DOE Complex has raised concerns that flammable gases other than hydrogen in waste containers could present a hazard. Subsequent analysis and review (HNF-25634) determined that quantifiable data were not available to prove concentrations of flammable gases other than hydrogen are below their lower flammability limits during and immediately following venting operations. The hydrogen deflagration event is considered to be bounding for the flammable gas deflagration event due to frequency, low ignition energies, and energy generated upon ignition. Nevertheless, the potential presence of

VOCs in the waste containers requires controls that have been incorporated into HNF-15280 and HNF-31228, *Justification for Continued Operations Drums with Evidence of Prohibited Items*, to confirm that the headspace gases other than hydrogen are nonflammable either by sampling or monitoring.

Analysis of SWOC waste (HNF-9411, *Analysis of Available Hydrogen Data and Accumulation of Hydrogen in Unvented TRU Drums*) indicates that hydrogen accumulation is not expected to be a concern in 95% of the drums handled. For drums where hydrogen accumulation may be a concern (estimated to be fewer than 900 drums), some retrieval and processing operations are expected to have a higher likelihood of creating the conditions necessary for container deflagration. The application of polyurea to the exterior of containers does not impact the conclusions of HNF-9411.

It is also possible that flammable gases could accumulate if the vent should fail; the most likely failure mechanism would be plugging. DOE Complex experience shows a relatively low rate of vent failure. For example, Rocky Flats found that of the 1300 drum vents that have been flow tested since 2000, 1.8% had either high or low flow-through and 0.08% was plugged due to either corrosion or vent surface coating (Defense Nuclear Facilities Safety Board letter, *RFETS Activity Report for the Week Ending April 12, 2002* [Owen 2002]). No plugged vents have been found at the SWOC. However, some waste stored at the low-level burial grounds may contain chemical constituents (primarily limited quantities of chloride salts and organics) that could cause corrosion of vents because waste acceptance criteria at the time of burial were not as mature as they are today. Available data indicate the presence of such chemicals is possible in up to 5% of the containers. Therefore, a low percentage of the drums managed at the SWOC and other Hanford projects is expected to show some evidence of vent plugging or failure.

In addition to the drummed waste, there are boxes that may also be used to transport waste materials that could be coated with polyurea to fix surface contamination. However, radioactive surface contamination on the plywood, FRP, or metal box will likely be discovered near a leak path. This is where the polyurea coating will be applied if not fully coating the box. It follows that any package fully coated with polyurea will diffuse flammable gases consistent with the physical properties of the polyurea, not the original package building materials. The DOE-approved transportation safety documents require that flammable gas accumulation inside a package be determined prior to being offered for transportation. HNF-30657 (Draft), *One-Time Request for Shipment Prohibited Conditions*, states:

> "Prohibited-condition containers for which there is evidence that they exceed the DOE/RL-2001-36, Appendix G, Table 3, hydrogen concentration limits will be overpacked in vented containers meeting DOT 7A Type A requirements and placed inside an IP-2 container. All overpack and IP-2 containers shall be vented. It is judged to be extremely unlikely that a deflagration accident within the inner container (drum or box) will result in a failure of the entire packaging system and release radioactive material to the environment."

Therefore, fully sealed packages that have an accumulation of flammable gases will be vented such that the concentrations are less than DOE/RL-2001-36, Appendix G, Table 3, or the specified controls from DOE-approved transportation safety documents will be implemented. The mechanism for sealing the exteriors of these containers will not impact the flammable gas controls specific to the accumulation inside the containers during transportation activities or operations.

The area of interest to this technical report is the package that is fully encapsulated with polyurea and then placed into an overpack for any reason. The polyurea coating on the exterior of a container that is placed inside another package becomes part of the payload. According to HNF-EP-0063, the generators of packaged waste are responsible for demonstrating that there is no potential to generate a flammable gas or that the vent mechanism is adequate to ensure that any combination of flammable gases generated since the package was sealed will remain below the flammable atmosphere. A 208 L (55-gal) drum fully encapsulated with polyurea and placed into an unvented 322 L (85-gal) overpack is judged to provide a reasonable assessment of the flammable gas accumulation in the void space of the 322 L (85-gal) overpack specifically from the gamma radiolysis of polyurea. A polyurea-coated box placed into a larger box will have more mass of polyurea, but will also have a larger void space, a larger surface area for diffusion of the flammable gas, and a mass fraction of polyurea assumed to not be larger than the overpacked 208 L (55-gal) drum. All overpack containers are vented. Therefore, without quantitative analysis the overpacked 208 L (55-gal) package is judged to be reasonable. The cured polyurea is composed primarily of solid organic compounds, so estimations of the polyurea contribution to hydrogen generation inside an overpack are presented in the next section.

3.9.1 Hydrogen Generation Calculation

This section investigates the gas generated with 500 g and 200 g of TRU waste source term that is 20-year aged 12% ^{240}Pu with ^{241}Am distributed in a matrix of 34 vol% cellulose, 31 vol% plastics, and 35 vol% noncombustible waste in a 208 L (55-gal) drum with an exterior coating of polyurea (HNF-8739, SARAH) placed into a 322 L (85-gal) overpack. Cellulose is the major constituent of paper and textiles made of cotton, linen, and other plant fibers. The polyurea is modeled as high-density polyethylene Marlex[6]-50 in the hydrogen calculations. The 500 g is based on the maximum inventory of a single-container material at risk for waste management accidents (HNF-8739, Table 3-2). Decay of the source term will begin January 1, 1979, with closure of the 208 L (55-gal) drum on December 31, 1980. The drum is coated with a 500 mil layer of polyurea over its entire surface. Before coating with polyurea, the drum exterior is not contaminated. After coating, the drum is placed into a 322 L (85-gal) drum with a NucFil[7]-19DS or -013 installed and then has a NucFil-007LS inserted through the lid of the 322 L (85-gal) drum into the 208 L (55-gal) drum. This calculation will determine the impact of the source term on the waste and polyurea over a five-year period and the resultant gas generation. The five-year analysis is conservative because DOE/RL-2001-36, Section 7.3.1.2.7(c)(2), describes a package gas generation potential under normal conditions for a one-year period beginning when the package is prepared for transport.

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[6] Marlex is a registered trademark of the Phillips Petroleum Company, Woodlands, Texas.
[7] NucFil is a registered trademark of Nuclear Filter Technology, Inc., Lakewood, Colorado.

The calculations determined that the unvented void of the 322 L (85-gal) drum containing a 208 L (55-gal) drum with 500 g of TRU with 12% ^{240}Pu contains 1.9% hydrogen and without polyurea contains 0.026% hydrogen. For comparison purposes the hydrogen gas calculations for a 322 L (85-gal) drum containing a 208 L (55-gal) container with 200 g of TRU with 12% ^{240}Pu contains 0.78% hydrogen and without polyurea contains 0.01% hydrogen. The application of polyurea to a container that is then overpacked raises the projected hydrogen level of the overpack, but not appreciably. The overpacks are vented in an effort to reduce the potential of a deflagration. The Radcalc 4.0 (DTS-SQA-009.1, *Radcalc Volume I: User's Manual*) runs are presented in Appendix D and summarized in Table 3-2.

Table 3-2. Gas Generation Summary.

	500 g			200 g		
	With polyurea	Without polyurea	Hydrogen	With polyurea	Without polyurea	Hydrogen
Mass of 208 L (55 gal) and waste	90.6 wt%	99.7 wt%	With polyurea 1.9 %	90.6 wt%	99.7 wt%	With polyurea 0.78 %
Mass of the wooden shims	0.25 wt%	0.3 wt%		0.25 wt%	0.3 wt%	
Mass of the polyurea	9.14 wt%	0	Without polyurea 0.026 %	9.14 wt %	0	Without polyurea 0.01 %
Total mass	399.6 kg	363.06 kg		399.6 kg	363.06 kg	

3.10 TIEDOWN AND PACKAGE RIGGING

The tiedown systems required by safety-basis documentation for packages and DOE/RL-2001-36 shall be implemented as described in the safety-basis documents for each packaging system. Containers transported on an open or in a covered conveyance must comply with the tiedown system required for that packaging system. No integral lifting or tiedown devices are provided on drums. Generally lifting and/or tiedown devices are not on other containers unless specifically designed and evaluated in the safety-basis documentation for the special case. The general rules for protection against shifting or falling cargo apply to all packages, and the application of polyurea coatings is not credited with adding to or subtracting from those protective rules.

The primary requirement for the application of polyurea is that containers must be structurally sound according to the criteria for that package. The additional dimensions created by the polyurea thickness may result in mechanical considerations for a tiedown system, but because the polyurea cannot exceed the weight limits for any package, the use of and robustness of the system cannot be impacted. Also, common methods used to achieve package damage control, such as speed limits, the use of sandbags or dunnage containers, and tiedowns, will not be affected by the application of polyurea.

Tiedown system designs are required to meet the applicable requirements of 49 CFR 393, "Parts and Accessories Necessary for Safe Operation," Subpart I, "Protection Against Shifting and

Falling Cargo," for the various types of packages and conveyances used on the Hanford Site. Generally, the designs must address the static forces applied at the center of gravity for the packages and the vertical and horizontal components both in the direction of the conveyance and the transverse direction, all based on the gross weight of the package. The designated chain binders or straps with ratchets placed over the top of packages for upward restraint are derived from a conservative tie down analysis. For example, HNF-SD-TP-SARP-004 describes the inertial loading specified for the SWB-enhanced tiedown that is approximately 10 times greater than the DOT requirements. It is judged that the tiedown analysis incorporates conservative parameters that compensate for any reduction of friction caused by the surface texture of a polyurea-coated bottom of a container versus the original container surface.

3.11 QUALITY ASSURANCE

Fluor Hanford, Inc. (FH), implements a quality assurance (QA) program as described in HNF-11724, *Fluor Hanford Safety Management Programs*, Chapter 14.0. The QA program described in HNF-11724 including applications of graded approach is applicable within the scope of the Project Hanford Management Contract (DE-AC06-96RL13200, *Contract Between the U.S. Department of Energy, Richland Operations Office, and Fluor Daniel Hanford, Inc.*) as required by DOE/RL-2001-36, Section 6.2. For design, fabrication, procurement, use, or maintenance of onsite fissile and Type B packagings, the requirements are as delineated in 10 CFR 71, "Packaging and Transportation of Radioactive Material," Subpart H, "Quality Assurance," or Nuclear Quality Assurance (ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*) or demonstrated equivalent. A key element of HNF-11724, Chapter 14.0, is described as "FH implements a QA program meeting the requirements of 10 CFR 830, 'Nuclear Safety Management,' Subpart A, 'Quality Assurance Requirements,' in accordance with HNF-MP-599, *Quality Assurance Program Description*." HNF-25689, *Transportation and Packaging Program Quality Assurance Program Plan*, defines the QA requirements that shall be implemented for the Transportation and Packaging activities. HNF-25689 applies to all FH Transportation and Packaging activities across the Hanford Site, which supports multiple contractors, projects, and/or facilities. The application of polyurea does not affect or adversely impact the implementation of the QA program as described in DOE/RL-2001-36, HNF-11724, or HNF-25689.

3.12 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

The maintenance of packages for transportation shall be per the manufacturers' recommendations, instructions, and/or the packaging safety-basis authorization(s). Whenever possible, empty and new packages shall be stored indoors or under protective cover to eliminate or minimize the effects of the sun, wind, rain, or other environmental conditions that could cause environmental degradation. Inspections of new and retrieved packages are required prior to transport. Because the intent of a polyurea coating is to enhance the weatherization or contamination control qualities of a package, it will likely be used primarily for retrieved packages. However, this technical report does not prohibit the transportation of new packages that have a polyurea coating.

The visual container inspections shall confirm that there is no container material degradation that could affect the structural integrity of the container. Inspections include external contaminations, external dose rates, container markings, container bottom, and closure features. The visual inspection of a container's external surface will not be possible when polyurea has been applied. However, the primary control for transportation is that containers must be structurally sound prior to the polyurea application and any polyurea coating must be fully cured. Sound containers that have been coated with polyurea and stored or staged, but subsequently are determined to require an overpack, for any reason, shall be overpacked prior to offering for transportation. Therefore, facility operations must confirm, document, and provide for review evidence that the structural integrity of the packages is sound, and the polyurea must be fully cured prior to being offered for transportation.

3.13 OPERATING PROCEDURES

This report does not identify controls or limitations placed on the transportation of packages specifically because of the application of polyurea, other than the requirement to ensure the polyurea is fully cured prior to acceptance for transportation activities. The package should be structurally sound prior to the application of a polyurea coating on the exterior, or the package may be an overpack with a payload that includes polyurea. The facility operating procedures that implement DOE/RL-2001-36 TSR controls derived from the transportation safety-basis documentation for each package are not duplicated in this report and are not modified, revised, or in any way changed by this report.

DOE/RL-2001-36, Appendix D, "Technical Safety Requirements for Hanford Onsite T&P," provides administrative limitations and controls that ensure the safe packaging and transportation of hazardous materials on the Hanford Site. These administrative controls address the provisions relating to organization and management, procedures, recordkeeping, audits, and specific program requirements for risk reduction necessary to ensure safe operation of the packaging system. The TSRs require a formal program that includes organization structure, nuclear criticality safety, gas accumulation minimization, package damage ratio minimization for risk-based packages, surveillance and maintenance, and configuration management. The key elements of required programs are implemented through facility operating procedures. This report does not change operating procedures that implement the transportation safety-basis documents, other than the requirement to ensure the polyurea is fully cured prior to acceptance for transportation activities.

Polyurea is not credited with any required mitigating feature that should be implemented in facility operating procedures or controls. The containers with an external application of polyurea should be structurally sound according to the criteria described in the facility CMP, which generally includes the waste acceptance criteria. The utilization of polyurea as part of contamination control has no impact on the requirements for transportation of polyurea-coated packages because the polyurea is not credited as a mitigating feature.

4.0 REFERENCES

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APPENDIX A

ENVIROLASTIC AR425 DATA SHEET AND INSTACOTE INFORMATION DATA

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Figure 1. Envirolastic AR425 – Manufacturer's Data Sheet

THE SHERWIN-WILLIAMS COMPANY

ControlTech
Tank Linings,
Containment &
Corrosion Control
Coatings

INDUSTRIAL & MARINE COATINGS

TRM.85

ENVIROLASTIC® AR425

PART A B81V3200
PART B B81-3200

ISOCYANATE SERIES

PRODUCT INFORMATION

Revised 2/04

PRODUCT DESCRIPTION

ENVIROLASTIC AR425 is a 100% solids, spray-applied, aromatic polyurea coating and lining system, which exhibits extraordinary toughness and elastomeric performance characteristics. It can be applied at thicknesses of 30-250 mils or greater in multiple passes during a single application.

- Fast cure - short down time
- No VOCs and low odor
- Seamless flexible and waterproof
- Chemical resistant
- Impact, tear,and abrasion resistant
- Bridges moving cracks to 1/8"
- Retains physical properties at -20°F to 250°F
- Acceptable for use in USDA inspected facilities
- Available with an antimicrobial agent to prevent micro-organisms from degrading the product

RECOMMENDED USES

Designed for use in immersion or atmospheric exposure as a tough, flexible, impact resistant, waterproof coating and lining system. Ideally suited for use in areas to include:

- Water & wastewater linings
- Tank linings
- Cooling tower linings
- Aquariums
- Mechanical rooms
- Geotextile linings
- Fuel storage & containment
- Marine bridge and deck
- Offshore platforms
- Manhole and sewer linings
- Basins and reservoirs
- Cold storage areas
- Waterparks & theme parks
- Secondary containment
- Landscape
- Pipe line coating and lining
- Marine bilge and tanks
- Tunnels

PRODUCT CHARACTERISTICS

Finish: Semi-Gloss

Color: White, Light Gray, Medium Gray, Dark Gray, Black, Beige, Tile Red Siver Metallic, Caribbean Green

Volume Solids: 100%

VOC (calculated): 0

Mix Ratio: 1:1

Recommended Spreading Rate per application:

Wet mils:	30.0 - 250.0
Dry mils:	30.0 - 250.0
Coverage:	6 - 53 sq ft/gal approximate

Drying Schedule @ 30.0 mils wet @ 73°F and 50% RH:

To touch:	45 seconds
To recoat:	
minimum:	45 seconds
maximum:	16 hours
Gel time:	15 seconds
Tack free:	45 seconds
Light traffic:	2 hours
To cure:	24 hours

If maximum recoat time is exceeded, abrade surface before recoating. Drying time is temperature, humidity, and film thickness dependent.

Pot Life: None

Sweat-in Time: None

Viscosity (mixed): 550 cps

Flash Point: 200°F

Shelf Life: 12 months, unopened
Store indoors at 40°F to 100°F.

Reducer: Not recommended

Clean Up: Butyl Cellusolve™ (R6K25) or Dowanol PM™

PERFORMANCE CHARACTERISTICS

Adhesion
Method: ASTM D4541
Results: Concrete: 350 psi
Steel: 2,000 psi
Wood: 250 psi

Salt Spray Corrosion
Method: ASTM B117, 3000 hrs
Results: Blisters: None
Corrosion from scribe: 7.0 mm
Elcometer adhesion: 2,000 psi

Tear Strength
Method: ASTM D638
Result: 495 pli

Tensile Modulus
Method: ASTM D 638
Results: 100% modulus: 1,280 psi
300% modulus: 2,100 psi

Abrasion Resistance
Method: ASTM D4060
Result: 1000 g 1000 cycles CS-17: 6 mg loss

Coefficient of Linear Thermal Expansion
Method: ASTM C531 (in/in/°F)
Result: 4×10^{-5}

Crack Bridging (@ -26°C (-15°F) @ 1/8")
Method: ASTM C836
Result: Passed

Fire Test of Roof Covering
Method: ASTM E108 (comparable to UL 790)
Result: Class A

Gardner Impact
Method: ASTM D2794 (1/32" steel panels)
Result: >160 in-lbs, direct and indirect

Mandrel Bend
Method: ASTM D522 Conical Bend (1/32" steel panel)
Result: Pass

QUV Weatherometer
Method: ASTM G53, 3000 hours, UVB 313 bulb
Result: Property Retention >90%

Surface Burning Characteristics (Tunnel Test) @ 20.0 mils dft
Method: ASTM E84 (Rating: Class 1)
Results: Flame Spread: 10
Smoke Density: 35

Durometer Hardness
Method: ASTM D2240
Result: Shore D-51

Tensile Strength
Method: ASTM D638
Result: 3,000 psi

Tensile Elongation
Method: ASTM D638
Result: 425%

Water Vapor Transmission
Method: ASTM E96
Result: 0.02 perm

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Figure 1. Envirolastic AR425 – Manufacturer's Data Sheet (cont'd)

THE SHERWIN WILLIAMS COMPANY

ControlTech Tank Linings, Containment & Corrosion Control Coatings

TRM.85

ENVIROLASTIC® AR425

PART A	B81V3200	ISOCYANATE
PART B	B81-3200	SERIES

INDUSTRIAL & MARINE COATINGS

PRODUCT INFORMATION

RECOMMENDED SYSTEMS

Steel (lining):
1 ct. EnviroLastic AR425 @ 60.0 - 80.0 mils dft*

Steel, with hold primer (lining):
1 ct. Copoxy Shop Primer @ 1.0 -1.5 mils dft
1 ct. EnviroLastic AR425 @ 60.0 - 80.0 mils dft*

Aluminum, Galvanized Steel, Zinc Rich Coatings:
1 ct. DTM Wash Primer @ 0.7 - 1.3 mils dft
1 ct. Envirolastic AR425 @ 30.0 - 40.0 mils dft

Concrete (lining):
1 ct. Corobond HS Epoxy Primer @ 3.0 - 4.0 mils dft
1 ct. EnviroLastic AR425 @ 60.0 - 80.0 mils dft*

Concrete (containment and flooring):
1 ct. Corobond HS Epoxy Primer @ 3.0 - 4.0 mils dft
1 ct. EnviroLastic AR425 @ 40.0 - 60.0 mils dft
1-2 cts Sher-Tuff Urethane @ 3.0 - 5.0 mils dft/ct
Note: When topcoating with Sher-Tuff Urethane or Cor-Cote HCR FF, allow AR425 to cure for one hour.

Concrete (containment, flooring and linings):
1 ct. Corobond HS Epoxy Primer @ 3.0 - 4.0 mils dft
1 ct. EnviroLastic AR425 @ 60.0 - 80.0 mils dft*
2 cts. Cor-Cote HCR FF @ 15.0 - 20.0 mils dft/ct

Concrete (mechanical equipment room):
1 ct. Corobond HS Epoxy Primer @ 3.0 - 4.0 mils dft
1 ct. EnviroLastic AR425 @ 30.0 - 40.0 mils dft
1 cts. EnviroLastic AR200 HD (texture) @ 10.0 - 20.0 mils dft

Concrete, low temperature or fast set:
1 ct. Corobond LT Epoxy Primer @ 4.0 - 8.0 mils dft
1 ct. EnviroLastic AR425 @ 30.0 - 40.0 mils dft*

Geo-Textile Lining (earthen base):
1 ct. Geo-textile non-woven, 3-4oz. Amoco "Petromat"Style 4599
1 ct. EnviroLastic AR425 @ 80.0 - 100.0 mils dft*

*When used as a lining in immersion service, a minimum total dry film thickness of 60.0 mils is required.

The systems listed above are representative of the product's use. Other systems may be appropriate.

SURFACE PREPARATION

Surface must be clean, dry, and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.

Refer to product Application Bulletin for detailed surface preparation information.

Minimum recommended surface preparation:
Steel:
Atmospheric: SSPC-SP10/NACE 2, 2 mil profile
Immersion: SSPC-SP10/NACE 2, 3 mil profile
Concrete & Masonry:
Sandblast or shotblast to remove all laitance and achieve a profile equal to 80-100 grit sandpaper. Refer to SSPC-SP13/NACE 6 or ICRI Guide 03732.

TINTING

Do not tint.

APPLICATION CONDITIONS

Temperature:

Material:	150°F minimum, 170°F maximum
Air and surface:	-20°F minimum, 120°F maximum At least 5°F above dew point
Relative humidity:	80% maximum

Refer to product Application Bulletin for detailed application information.

ORDERING INFORMATION

Packaging:

Part A:	53 gallon drums
Part B:	53 gallon drums

SAFETY PRECAUTIONS

Refer to the MSDS sheet before use.

Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.

Figure 1. Envirolastic AR425 – Manufacturer's Data Sheet (cont'd)

THE SHERWIN-WILLIAMS COMPANY

ControlTech
Tank Linings, Containment & Corrosion Control Coatings

INDUSTRIAL & MARINE COATINGS

TRM.85A

ENVIROLASTIC® AR425

PART A B81V3200
PART B B81-3200

ISOCYANATE SERIES

APPLICATION BULLETIN

Revised 2/04

SURFACE PREPARATION

Surface must be clean, dry, and in sound condition. Remove all oil, dust, grease, dirt, loose rust, and other foreign material to ensure adequate adhesion.

Iron & Steel (immersion service)
Remove all oil and grease from surface by Solvent Cleaning per SSPC-SP1. Minimum surface preparation is Near White Metal Blast Cleaning per SSPC-SP10. Blast clean all surfaces using a sharp, angular abrasive for optimum surface profile (3 mils). Remove all weld spatter and round all sharp edges by grinding to a minimum 1/4" radius. Prime any bare steel the same day as it is cleaned or before flash rusting occurs.

Iron & Steel (atmospheric service)
Remove all oil and grease from surface by Solvent Cleaning per SSPC-SP1. Minimum surface preparation is Near White Metal Blast Cleaning per SSPC-SP10. Blast clean all surfaces using a sharp, angular abrasive for optimum surface profile (2 mils).Prime any bare steel the same day as it is cleaned or before flash rusting occurs.

Poured Concrete
New
For surface preparation, refer to SSPC-SP13/NACE 6. Surface must be clean, dry, sound, and offer sufficient profile to achieve adequate adhesion. Minimum substrate cure is 28 days at 73°F. Remove all form release agents, curing compounds, salts, efflorescence, laitance, and other foreign matter by sandblasting, shotblasting, mechanical scarification, or suitable chemical means. Refer to ASTM D4260. Rinse thoroughly to achieve a final pH between 10.0 and 13.0. Allow to dry thoroughly prior to coating.

Old
Surface preparation is done in much the same manner as new concrete; however, if the concrete is contaminated with oils, grease, chemicals, etc., they must be removed by cleaning with a strong detergent. Refer to ASTM D4258. Form release agents, hardeners, etc. must be removed by sandblasting, shotblasting, mechanical scarification, or suitable chemical means. If surface deterioration presents an unacceptably rough surface, Steel-Seam VSE epoxy filler is recommended to patch and resurface damaged concrete.
Fill all cracks, voids and bugholes with Steel-Seam VSE.

Always follow the ASTM methods listed below:
ASTM D4258 Standard Practice for Cleaning Concrete.
ASTM D4259 Standard Practice for Abrading Concrete.
ASTM D4260 Standard Practice for Etching Concrete.
ASTM F 1869 Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete.

Immersion Service:
In addition to the above surface preparation, Brush Blasting of the concrete surface is required.

APPLICATION CONDITIONS

Temperature:

Material:	150°F minimum, 170°F maximum
Air and surface:	-20°F minimum, 120°F maximum At least 5°F above dew point
Relative humidity:	80% maximum

APPLICATION EQUIPMENT

The following is a guide. Changes in pressures and tip sizes may be needed for proper spray characteristics. Always purge spray equipment before use with listed reducer. Any reduction must be compatible with the existing environmental and application conditions.

Reducer .... Not recommended

Clean-up .... Butyl Cellusolve™ (R6K25) or Dowanol PM™

Plural Component Heated Spray Equipment:
Equipment .... Gusmer H-20/35
Gun .... GX7 DI,GX7-400, or GX-8
Fluid Pressure .... 2,200 psi
Air Pressure .... 100 psi
Inlet Strainer Screen ..... 30 mesh
Gun Screen .... 80 mesh

If specific application equipment is listed above, equivalent equipment may be substituted.

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Figure 1. Envirolastic AR425 – Manufacturer's Data Sheet (cont'd)

THE SHERWIN-WILLIAMS COMPANY

ControlTech
Tank Linings,
Containment &
Corrosion Control
Coatings

INDUSTRIAL & MARINE COATINGS

TRM.85A

ENVIROLASTIC® AR425

PART A B81V3200 ISOCYANATE
PART B B81-3200 SERIES

APPLICATION BULLETIN

APPLICATION PROCEDURES

Surface preparation must be completed as indicated. Route and seal all cracks greater than 1/16" with EnviroLastic JS80 SL.

Mixing Instructions:
Agitate resin blend (B) component thoroughly with a drum mixer before use to disperse pigment and assure homogeneity. Do not thin. Do not mix "A" and "B" resins together. **Caution: Do not agitate in air and moisture.**

Apply coating/lining at the recommended film thickness and spreading rate as indicated below:

Recommended Spreading Rate per application:

Wet mils:	30.0 - 250.0
Dry mils:	30.0 - 250.0
Coverage:	6 - 53 sq ft/gal approximate

Drying Schedule @ 30.0 mils wet @ 73°F and 50% RH:

To touch:	45 seconds
To recoat:	
minimum:	45 seconds
maximum:	16 hours
Gel time:	15 seconds
Tack free:	45 seconds
Light traffic:	2 hours
To cure:	24 hours

If maximum recoat time is exceeded, abrade surface before recoating. Drying time is temperature, humidity, and film thickness dependent.

Pot Life: None

Sweat-in Time: None

Application of coating above maximum or below minimum recommended spreading rate may adversely affect coating performance.

PERFORMANCE TIPS

For concrete, always perform Calcium Chloride test as per ASTM F1869. Do not proceed with MVE >3 lbs.

For immersion applications, a minimum total dry film thickness of 60 mils is required. Always apply lining material in at least two applications. Spark test in accordance with ASTM D5162 for steel or ASTM D4787 for concrete after application of the first coat. Repair holidays found prior to application of second coat.

May be applied in one or two coats to achieve the recommended film thickness.

For steel, stripe coat all chine, welds, bolted connections, and sharp angles to prevent early failure in these areas. For concrete, all cracks must receive a 6" wide by 30 mil dft detail coat.

Use only heated, plural component equipment capable of producing 2,500 psi at 160°F and 2 gallon/minute output consistently.

In order to avoid blockage of spray equipment, clean equipment before use or before periods of extended downtime with Butyl Cellusolve™ (R6K25), Dowanol PM™, or Propylene Glycol.

While spraying, use a 50% overlap with each pass of the gun to avoid holidays, bare areas, and pinholes. If necessary, cross spray at a right angle.

Spreading rates are calculated on volume solids and do not include an application loss factor due to surface profile, roughness or porosity of the surface, skill and technique of the applicator, method of application, various surface irregularities, material lost during mixing, spillage, overthinning, climatic conditions, and excessive film build.

Do not agitate in air and moisture.

Consult your Sherwin-Williams representative for specific application and performance recommendations.

Refer to Product Information sheet for additional performance characteristics and properties.

CLEAN UP INSTRUCTIONS

Clean spills and spatters immediately with Butyl Cellusolve™ (R6K25) or Dowanol PM™. Clean tools and equipment immediately after use (including both "A" and "B" sides of plural component spray system) with Butyl Cellusolve™ (R6K25) or Dowanol PM™.

SAFETY PRECAUTIONS

Refer to the MSDS sheet before use.

Published technical data and instructions are subject to change without notice. Contact your Sherwin-Williams representative for additional technical data and instructions.

APPENDIX B

INSTACOTE SE FR MATERIAL SAFETY DATA SHEETS (MSDS) PART A, PART B, CURED PRODUCT, AND INFORMAL COMMUNICATION FROM THE VENDOR

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MSDS # 064670

MATERIAL SAFETY DATA SHEET

Trade Name: InstaCote™ SE FR Isocyanate Part "A"

Section I -General Information

Item Name: InstaCote™ SE FR Isocyanate, Part "A"

Manufacture: InstaCote, Inc.
160 C Lavoy Road
Erie, MI 48133

Date MSDS Prepared: December 6. 1995
Last Review Date: March 6, 2002
MSDS Preparers Name/Address: Prepared by manufacturer.
Product Description: Pre-polymerized Isocyanate Blend.
Multiple Parts Product (Y/N): Y

Section II – Hazardous Ingredient/Identity Information

Proprietary (Y/N): Y

Ingredient	CAS #	Exposure Limits (TWA)
4, 4'-diphenylmethane Di-isocyanate	101-68-8	0.02 ppm ceiling limit, OSHA 0.005 ppm ACGIH TLV, TWA
Mixed Isomers	26447-40-5	0.02 ppm ceiling limit, OSHA 0.005 ppm TLV, ACGIH

Section III-Physical/Chemical Characteristics

Appearance and Odor. Clear, amber color thick liquid with faint odor
Boiling Point: 738°F
Melting Point: 99°F
Vapor Pressure: 0.001 mm Hg @ 130°F
Vapor Density: No data
Specific Gravity: 1.140 @ 72°F
Decomposition Temp.: Above 738°F
Evaporation Rate: No data
Solubility (H_2O): 0.2% by wt @ 68°F
Percent Volatiles by Volume: unknown
Viscosity: 1300 cP (Brookfield #2 spindle @ 12 rpm) 72°F
pH: Not applicable

MATERIAL SAFETY DATA SHEET
InstaCote SE FR Isocyanate Prepolymer, Part "A"
August 19, 2002
PAGE 2

MSDS # 064670

Section IV - Fire and Explosion Hazard Data

Flash Point: 396°F C.O.C.
Lower Explosive Limit: Not Determined
Upper Explosive Limit: Not Determined
Extinguishing Media/Methods: Use dry chemical, CO_2, AFFF (foam). If only water is available Use very large volume. Reaction with water at elevated temperatures may be violent. Runoff water must be retained.
Special Fire Fighting Precautions: Full face shield, self-contained breathing apparatus with full protective gear.
Unusual Fire/Explosive Hazards: Isocyanate and water combined react to produce carbon dioxide. Contaminated, sealed containers may rupture.

Section V - Reactivity Data

Stable (Y/N): Y
Conditions to Avoid: High temperatures
Materials to Avoid: Product may react violently with water, alcohol, amines, acids, bases.
Hazardous Decomposition Products: Oxides of carbon, oxides of nitrogen, ammonia and trace amounts of Hydrogen cyanide.
Hazardous Polymerization: May occur. Avoid contamination with liquid water or water vapor.

Section VI - Health Hazard Data

Routes of Entry
Inhalation (Y/N): Y, May cause respiratory tract irritation(pulmonary edema, nasal discharge, coughing, chest pain. This product may cause respiratory sensitization, in which, after repeated exposures above the occupational exposure limit, hyper-reactive responses may occur in sensitized individuals following minimal doses.
Skin (Y/N): Y, Product exhibits skin sensitization. Some evidence indicates that skin contact may induce a respiratory sensitization reaction.
Ingestion (Y/N): Y, May cause digestive tract and gastrointestinal tract. Systemic ingestion effects are practically non-toxic.
Other: Y, Acute vapor exposures may temporarily cause hazy or blurred vision.
Contact Eye/Skin Hazards: Y, Product is a mild eye and skin contact irritant.
Carcinogenicity Data: No human or animal carcinogenic data is available.
IARC Monographs on the Evaluation of the Carcinogenic: None

First Aid Procedures:
Gross Inhalation: Move victim to fresh air environment. First administer oxygen, if available. Seek immediate medical attention.
Gross Ingestion: If victim is conscious, give at least two glasses of water. DO NOT

MSDS # 064670

INDUCE VOMITING. Seek medical assistance.

Skin Contact - Wash affected areas with soap and water. Wash soiled clothing

Section VI - Health Hazard Data (cont.)

before reuse.

Severe Eye Contact - Flush eyes with water for 15 minutes. Seek medical attention.

Section VII - Precautions for Safe Handling and Use

Personal Protective Equipment (Routine Use):

Respiratory Protection : Airborne concentrations of chemical should be maintained as low as possible. If vapors or mists are formed, use NIOSH/MSHA approved air supplied respirator to prevent overexposure.

Gloves: Recommend latex, butyl rubber, or nitrile gloves.

Eye Protection: Safety goggles or glasses with face shield are recommended.

Other: Recommend Tyvek suits or coveralls.

Work Practices: This product may be used in indoor or outdoor environments. Exposures to hazardous components are not expected to exceed permissible limits during routine daily use.

Ventilation: If vapors or mists are generated, local exhaust ventilation is recommended. Spill/Release Procedures: For major spills, call CHEMTREC 1-800-424-9300. Ventilate area and avoid breathing vapors. Use chemical cartridge respiratory protection and full protective clothing to clean large spills or spills in confined areas. Contain spill, and prevent entry into sewers and waterways.

Neutralization Procedures: Use 0.2-0.5% liquid detergent mixed with 3-8% Ammonium hydroxide or 5-10% sodium carbonate in water. Use 10 parts of solution for one part of Spill material. Allow 30 minutes to deactivate before placing spilled material into drums. Do not mix with any other waste material.

Waste Disposal Procedures: This material is not a listed hazardous waste, nor does it exhibit any hazardous waste characteristic.

Storage/Handling Procedures: Store product in a dry environment, away from strong bases and oxidizers. Do not place in contact with copper metal, copper alloys or zinc coated metals. Purge headspace in partially use container with dry nitrogen gas.

Section VIII-Transportation Information:

Bill of Lading description: Liquid, NOS, (MDI), NA3082, PGIII

END

MSDS # 064671

MATERIAL SAFETY DATA SHEET

Trade Name: InstaCote™ SE FR Resin, Part "B"

Section I -General Information

Item Name: InstaCote™ SE FR Resin, Part "B"

Manufacture: InstaCote, Inc.
160 C. Lavoy Road
Erie, MI 48133
Phone 734-847-5260
Fax 734-847-9008

Date MSDS Prepared: December 6, 1995
Last Review Date: March 6, 2002
MSDS Preparers Name/Address: prepared by manufacturer.
Product Description: Liquid aromatic polyamine/polyoxyalkyleneamine with An ammoniacal odor of various colors
Multiple Part Product (Y/N): Y (ISO Part "A" is other half of this 2 part system)

Proprietary (Y/N): Y

Section II – Ingredient/Identity Information

Ingredient	CAS #	Exposure Limits (TWA)
Aromatic Amine mixture	Proprietary	
Polyoxyalkyleneamine	9046-10-0	Not established
Diethyltoluenediamine	68479-98-1	Not established

Various pigments and or dyes can be present

Product is listed or hazardous according to one or more state Right To Know (SARA III) or federal Toxic Chemical Release Inventory, or Toxic Substance Control Act Laws.

Section III Physical/Chemical Characteristics

Appearance and Odor: Colored, glossy liquid with ammoniacal odor
Boiling Point: Not determined
Melting Point: Not determined
Vapor Pressure: Not determined

MSDS # 064671

Vapor Density: Not determined
Specific Gravity: 1.014 @ 69°F
Evaporation Rate: Not determined
Solubility (H_2O): <0.02% by wt. @ 69°F
Percent Volatiles by Volume: less than 0.001%
Viscosity: 855 cP (Brookfield, #2 spindle @ 12rpm, @ 69°F)
pH: Not applicable

Section IV - Fire and Explosion Hazard Data

Flash Point: > 275°F
Lower Explosive Limit: Not established
Upper Explosive Limit: Not established
Extinguishing Media/Methods: Use dry chemical, CO_2, AFFF (foam), or water.
Special Fire Fighting Precautions: None
Unusual Fire/Explosive Hazards: None

Section V - Reactivity Data

Stable (Y/N): Y
Conditions to Avoid: None
Materials to Avoid: Do not mix with nitrites, May react violently with acids.
Hazardous Decomposition Products: Oxides of Carbon, Oxides of Nitrogen, ammonia, aldehydes and ketones

Section VI - Health Hazard Data

Routes of Entry

Inhalation (Y/N): Y, May cause respiratory tract irritation (pulmonary edema), nasal discharge, coughing and chest pain. Prolonged exposure may result in permanent lung damage.

Skin (Y/N): Y, Product is expected to be toxic by dermal absorption.

Ingestion (Y/N): Y, May cause digestive tract irritation and respiratory tract irritation and lung damage upon aspiration.

Other: Y, Acute vapor exposure may temporarily cause hazy or blurred vision.

Contact Eye/Skin Hazards: This product is highly corrosive and may cause severe burns, redness, swelling, and blistering upon direct contact.

Carcinogenicity Data: No human carcinogenic data is available. Evidence of limited tumor

MSDS # 064671

growth
in animals.

IARC Monographs on the Evaluation of the Carcinogenic: None available.

First Aid Procedures:

Gross Ingestion: If victim is conscious, give at least two glasses of water. Do not induce vomiting. Seek immediate medical attention. Physician should evacuate stomach
by means least likely to cause aspiration.

Gross Inhalation: Move victim to fresh air environment. Seek immediate medical attention. Notify physician of corrosive nature of chemical.

Skin Contact - Wash affected areas with soap and water. Laundry soiled clothing before reuse.

Severe Eye Contact - Flush eyes with water for 15 minutes. Seek medical attention.

Section VII - Precautions for Safe Handling and Use

Personal Protective Equipment (Routine Use):

Respiratory Protection: In cases when excessive mists might be periodically created, use NIOSH/MSHA approved full or half face respirators with dust cartridges when pouring and mixing product.

Gloves: Recommend latex, butyl rubber, or nitrile gloves.

Eye Protection: Safety goggles or glasses recommended.

Other: Recommend Tyvek suits or coveralls.

Work Practices: This product is to be used both outdoors and in enclosed environments with adequate respiratory and, or ventilation controls. Do not use in presence of flames or sparks.

Ventilation: If routine indoor use is required, or in the presence of excess mist generation, local exhaust ventilation is recommended.

Spill/Release Procedures: Excess spilled product, if uncontaminated, may be cleaned and disposed of as ordinary waste. No special clean up procedures are recommended.

Neutralization Procedures:

Waste Disposal Procedures: This material is not a listed hazardous waste, nor does it exhibit any hazardous waste characteristic.

Storage/Handling Procedures: Store product in a dry environment, away from strong acids and oxidizers.

End

MSDS # 064672

MATERIAL SAFETY DATA SHEET

Trade Name: InstaCote™ SE FR Cured Plastic

Section I -General Information

Item Name: InstaCote™ SE FR Cured plastic

Manufacture: InstaCote, Inc.
160 C. Lavoy Road
Erie, MI 48133
Phone 734-847-5260
Fax 734-847-9008

Date MSDS Prepared: July 8, 2002
Last Review Date: July 8, 2002
MSDS Preparers Name/Address: prepared by manufacturer.
Product Description: MDI Polyurea Plastic
Multiple Part Product (Y/N): Y (Finished Part of "A & B" of this 2 part system)

Proprietary (Y/N): Y

Section II – Ingredient/Identity Information

Not hazardous

Section III Physical/Chemical Characteristics

Appearance and Odor: No odor, color usually black
Boiling Point: Not determined
Melting Point: Not determined
Vapor Pressure: Not determined
Vapor Density: Not determined
Specific Gravity: Not determined
Evaporation Rate: Not determined
Solubility (H_2O): None
Percent Volatiles by Volume: less than 0.001%
Viscosity: None solid
pH: Not applicable

Section IV - Fire and Explosion Hazard Data

Flash Point: N/A
Lower Explosive Limit: Not determined
Upper Explosive Limit: Not determined
Extinguishing Media/Methods: Use dry chemical, CO_2, AFFF (foam), or water.
Special Fire Fighting Precautions: Full face shield, self contained breathing apparatus with full protective gear.
Unusual Fire/Explosive Hazards: See Omega Labs Fire testing results

Section V - Reactivity Data

Stable (Y/N): Y
Conditions to Avoid: Temperature in excess of 350°F
Materials to Avoid: Concentrated strong acids
Hazardous Decomposition Products: Oxides of Carbon, Oxides of Nitrogen, ammonia, aldehydes and ketones

Section VI - Health Hazard Data

Routes of Entry
Inhalation (Y/N): N
Skin (Y/N): N
Ingestion (Y/N) N
Other: (Y/N) N

Contact Eye/Skin Hazards: (Y/N) N
Carcinogenicity Data: (Y/N) N
IARC Monographs on the Evaluation of the Carcinogenic: (Y/N) N

First Aid Procedures:

Gross Ingestion: (Y/N) N
Gross Inhalation: (Y/N) N
Skin Contact - (Y/N) N
Severe Eye Contact - (Y/N) N

Section VII - Precautions for Safe Handling and Use

Personal Protective Equipment (Routine Use):

Respiratory Protection: (Y/N) N
Gloves: (Y/N) N
Eye Protection: (Y/N) N
Other: Recommend Tyvek suits or coveralls.

Work Practices: (Y/N) N
Ventilation: (Y/N) N
Spill/Release Procedures: (Y/N) N
Neutralization Procedures:

MSDS # 064672

Waste Disposal Procedures: (Y/N) N
Storage/Handling Procedures: (Y/N) N

INSTACOTE

ENVIRONMENTAL COATINGS

To: Gary Dukelow 3/23/07

From: Tom Nachtman

Here is the consolidated list of questions that will be needed to answer DOE's concerns; all of them apply to the cured polyurea:

1. What happens when polyurea is cut with a rotary or reciprocating saw as far as hazardous vapors given off or any other effect? For example, when a coated wooden box has to have its top cut off.

We have a lot of experience using hole saws and saws-alls to cut cured polyurea. There are no hazardous vapors. The heat generated by the process of cutting does not gum up the blades.

2. What if a coated metal box is cut with an acetylene torch; are there any hazardous vapors or any other effect?

We strongly do not recommend using an acetylene torch, however if you use an acetylene torch it will burn in the area of the flame and will go out when flame is removed. Generally gases produced are carbon dioxide, carbon monoxide and nitrogen oxide. InstaCote does have customers that weld steel racks which are sprayed with polyurea. This is accomplished with removing the InstaCote and spot welding a bare area.

3. Information on the effects of radiation; Envirolastic was tested to 10^7 Rad with essentially no effects except for color modification.

InstaCote polyurea was tested to ~~10.0~~10^6 R? ~~Mrad~~ Gamma Dose with little effect to the properties. A discoloration is all one should expect to see. The University of Michigan Irradiation study is available upon request.

4. Effects of UV

UV degradation is not to be expected with Polyurea. InstaCote has had material outside for 15 years with minimal effect on the elastomer. Some slight graying and loss of gloss is to be expected. The elastomer will not lose its integrity due to UV exposure. Rocky Flats sprayed many large objects and staged them for up to a year outside with no visible effects seen to the InstaCote SE FR.

5. Effects of thermal cycling from ambient weather conditions

Polyurea was originally developed for use in the automotive industry and is still used today because of the ability of the material to withstand thermal cycling and seasonal variations.

6. Basis or similarity with Envirolastic 425 MSDS part B statement (previously faxed) that "dust at sufficient concentrations can form explosive mixtures with air.

InstaCote polyurea does not create explosive mixtures of dust during dispensing. Explosive mixtures would require combustible gases, vapors, mist, or combustible dust and fibers. InstaCote polyurea system is never sprayed using a single component ie. Part B.

7. As many of the equivalent "Performance Characteristics" as you have compared to the attached Envirolastic 425 data sheet

	S-W properties	InstaCote SE FR- HCET (detailed report)
Tensile	3000#	2500 to 2700#
Elongation	425%	350%
Hardness	51- D	54-D
Tack free	45 seconds	25 - 30 seconds
Gel time	15 seconds	3 - 4 seconds
Cure	24 hours	24 hours

8. Temperature range that physical characteristics are retained

InstaCote polyurea physical properties have serviceability from -40° F to 350° F. The Hemispheric Center for Environmental Technology final report is available upon request.

9. Moving crack bridging capability.

Bridging of cracks and filling voids areas is accomplished through craft technique during dispensing. This will be a part of the training.

10. Life expectancy of cured product

Based on the available information we have to date, it is felt that a properly formulated and prepared polyurea elastomer system, like that of the InstaCote product line, would survive a minimum of 100 years in your buried and above ground application areas, especially at the $\frac{1}{4}$ inch applied thickness. This is based on the testing, flexibility of the system, chemical resistance and thermal properties.

11. Are there any conditions that might promote embrittlement or cracking?

No, the cured polyurea elastomer "InstaCote" is very stable and resistant to environmental conditions.

160 C. LAVOY RD. ERIE, MI 48133 ■ PHONE (734) 847-5260 ■ FAX (734) 847-9008

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APPENDIX C

FLAME SPREAD TESTING DATA AND COMBUSTION PRODUCTS

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ASTM E84-00a

SURFACE BURNING CHARACTERISTICS

InstaCote SE FR (Resin Test No: 2)

Report No. 15806 - 112542

November 7, 2002

Prepared For:

InstaCote, Inc.
160 C Lavoy Road
Erie, MI 48133, U.S.A.

ACCREDITED

ABSTRACT

Test Material:	**InstaCote SE FR (Resin Test No: 2)**
Test Standard:	**ASTM E84-00a Standard Test Method for SURFACE BURNING CHARACTERISTICS OF BUILDING MATERIALS (ANSI 2.5, NFPA 255, UBC 8-1, UL 723)**
Test Date:	**November 7, 2002**
Test Sponsor:	**InstaCote, Inc.**
Test Results:	**FLAME SPREAD INDEX = 20** **SMOKE DEVELOPED INDEX = 115**

The description of the test procedure and specimen evaluated, as well as the observations and results obtained, contained herein are true and accurate within the limits of sound engineering practice. These results are valid only for the specimen(s) tested and may not represent the performance of other specimens from the same or other production lots.

**Omega Point Laboratories, Inc. authorizes the client named herein to reproduce this report only if reproduced in its entirety.
The test specimen identification is as provided by the client and Omega Point Laboratories accepts no responsibility for any inaccuracies therein.**

Ernie Schmidt
Director, Flammability Testing

Date: November 7, 2002

William E. Fitch, P.E. No. 55296
Executive Vice President

Date: November 7, 2002

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I. INTRODUCTION

This report describes the results of the ASTM E84 Standard Test Method for SURFACE BURNING CHARACTERISTICS OF BUILDING MATERIALS (1) , a method for determining the comparative surface burning behavior of building materials. This test is applicable to exposed surfaces, such as ceilings or walls, provided that the material or assembly of materials, by its own structural quality or the manner in which it is tested and intended for use, is capable of supporting itself in position or being supported during the test period.

The purpose of the method is to determine the relative burning behavior of the material by observing the flame spread along the specimen. Flame spread and smoke density developed are reported, however, there is not necessarily a relationship between these two measurements.

"The use of supporting materials on the underside of the test specimen may lower the flame spread index from that which might be obtained if the specimen could be tested without such support... This method may not be appropriate for obtaining comparative surface burning behavior of some cellular plastic materials... Testing of materials that melt, drip, or delaminate to such a degree that the continuity of the flame front is destroyed, results in low flame spread indices that do not relate directly to indices obtained by testing materials that remain in place."

This test method is also published under the following designations:

ANSI 2.5
NFPA 255
UBC 8-1 (42-1)
UL 723

This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

---

(1) American Society for Testing and Materials (ASTM), Committee E-5 on Fire Standards

II. PURPOSE

The ASTM E84 (25 foot tunnel) test method is intended to compare the surface flame spread and smoke developed measurements to those obtained from tests of mineral fiber cement board and select grade red oak flooring. The test specimen surface (18 inches wide and 24 feet long) is exposed to a flaming fire exposure during the 10 minute test duration, while flame spread over its surface and density of the resulting smoke are measured and recorded. Test results are presented as the computed comparisons to the standard calibration materials.

The furnace is considered under calibration when a 10 minute test of red oak decking will pass flame out the end of the tunnel in five minutes, 30 seconds, plus or minus 15 seconds. Mineral fiber cement board forms the zero point for both flame spread and smoke developed indexes, while the red oak flooring smoke developed index is set as 100.

III. DESCRIPTION OF TEST SPECIMENS

Specimen Identification:	InstaCote SE FR (Resin Test No: 2)
Date Received:	10/25/02
Date Prepared:	October 25, 2002
Conditioning (73°F & 50% R.H.):	13 days
Specimen Width (in):	24
Specimen Length (ft):	24
Specimen Thickness:	0.516 in.
Material Weight:	N/A oz./sq. yd.
Total Specimen Weight:	155.5-lbs.
Adhesive or coating application rate:	N/A

Mounting Method:

The specimen was self supporting and was placed directly on the inner ledges of the tunnel apparatus.

Specimen Description:

The specimen was described by the client as "InstaCote SE FR (Resin Test #2)". The specimen consisted of (5) 24" wide x 5 ft. long concrete panels coated with a blue fire retarded polyurea coating.

IV. TEST RESULTS

The test results, computed on the basis of observed flame front advance and electronic smoke density measurements are presented in the following table. In recognition of possible variations and limitations of the test method, the results are computed to the nearest number divisible by five, as outlined in the test method.

While no longer a part of this standard test method, the Fuel Contributed Value has been computed, and may be found on the computer printout sheet in the Appendix.

Test Specimen	Flame Spread Index	Smoke Developed Index
Mineral Fiber Cement Board	0	0
Red Oak Flooring	n/a	100
InstaCote SE FR (Resin Test No: 2)	**20**	**115**

The data sheets are included in the Appendix. These sheets are actual print-outs of the computerized data system which monitors the ASTM E84 apparatus, and contain all calibration and specimen data needed to calculate the test results.

V. OBSERVATIONS

During the test, the specimen was observed to behave in the following manner: Steady ignition began at 0:25 (min:sec). The test continued for the 10:00 duration.

After the test, the specimen was observed to be damaged in the following manner: The coating was consumed from 0 ft. - 10 ft. and there was a residual amount of black char. There was a light brown surface discoloration from 10 ft. - 24 ft.

APPENDIX

DATA SHEETS

ASTM E84 DATASHEETS

Client: INSTACOTE, INC.
Date: 11/7/02
Time: 10:20 AM
Test Number: 1
Project Number: 15806-112542
Operator: ES/EH
Specimen ID: "INSTACOTE SE FR (RESIN TEST #2), FIRE RETARDED POLYUREA COATING". THE SPECIMEN WAS SELF-SUPPORTING.

TEST RESULTS

FLAMESPREAD INDEX: 20

SMOKE DEVELOPED INDEX: 115

SPECIMEN DATA

Time to Ignition (sec):	25
Time to Max FS (sec):	196
Maximum FS (feet):	5.0
Time to 980 °F (sec):	Never Reached
Max Temperature (°F):	611
Time to Max Temperature (sec):	592
Total Fuel Burned (cubic feet):	43.31
FS*Time Area (ft*min):	42.7
Smoke Area (%A*min):	117.4
Fuel Area (°F*min):	5664.9
Fuel Contributed Value:	9
Unrounded FSI:	22.0

CALIBRATION DATA

Time to Ignition of Last Red Oak (sec):	51
Red Oak Smoke Area (%A*min):	101.00
Red Oak Fuel Area (°F*min):	8970
Glass Fiber Board Fuel Area (°F*min):	5325

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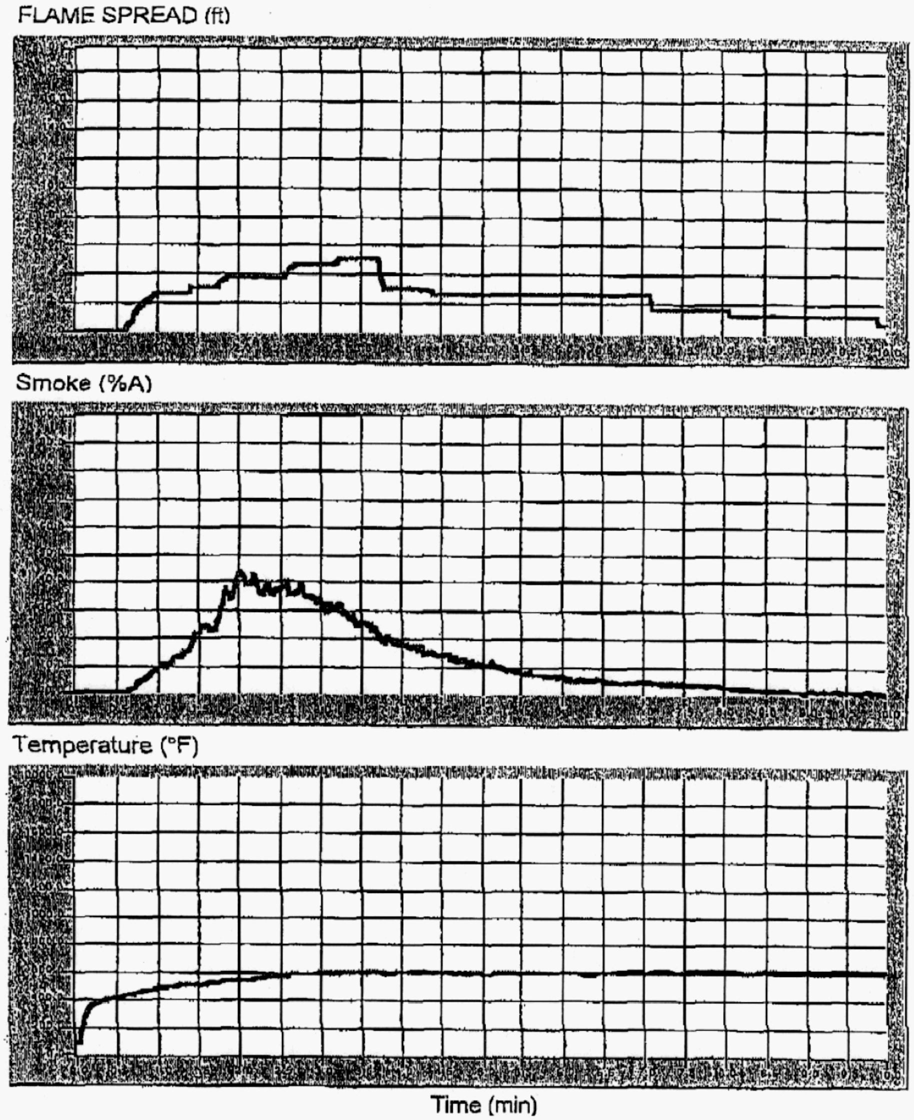
Figure 4. InstaCote Flame Spread Testing Data

Project No: 15806-112542



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BSS 7239-88
Test Method for Toxic Gas Generation by Materials on Combustion

InstaCote ML-2R Soft TR004 Blue

Project No. 15806-103043

April 8, 1998

Prepared for:

InstaCote, Inc.
160 C Lavoy Road
Erie, MI 48133
(734) 847-8997

Omega Point Laboratories, Inc.
16015 Shady Falls Road
Elmendorf, Texas 78112-9784
210-635-8100 / FAX: 210-635-8101 / 800-966-5253
www.opl.com / e-mail: moreinfo@opl.com

INTRODUCTION

The determination of the gaseous products of smoke (often called "fire gases"), including those due to either pyrolysis or combustion, is a difficult problem. The composition of the smoke from most products is affected by the nature of the fire test procedure that created the smoke (i.e., flaming or nonflaming conditions, specimen size and configuration, external applied heat flux, etc.). Gas sampling considerations include the time at which sampling of the atmosphere was initiated and the duration of the sampling (smoke concentrations can change with time); the position of the sampling probe (concentrations can change with location in a chamber); the method of sampling (a major cause of error in fire gas analysis); and the actual method of analysis. Sampling and analysis of fire gases are described in some detail in ASTM E800 ("Standard Guide for Measurement of Gases Present or Generated During Fires"), to which the reader is referred.

One of the common test methods for creating "smoke" is the ASTM E662 smoke chamber (a method fundamentally the same as BSS 7238), which provides for both flaming and nonflaming combustion of 76 mm x 76 mm (3-in. x 3-in.) specimens exposed to an external radiant heat flux of 25 kW/m^2. The smoke is retained within the confines of the 500-L chamber. For this test procedure, analysis of gaseous components is performed starting at four minutes into the test run. Only the flaming exposure is specified. Actual analysis of the gases of interest may be performed directly using Dräger® colorimetric gas analysis tubes; by trapping the gases in solution impingers (bubblers) and subsequently analyzing the anions by ion-selective electrodes, titration or liquid chromatography; or by instruments designed to measure the specific gas(es) of interest (e.g., gas chromatographic methods, NDIR or FTIR analyzers).

The following gases are required to be measured by this test standard:

CO	carbon monoxide
HF	hydrogen fluoride
HCl	hydrogen chloride
NO_x	nitrogen oxides (both NO, nitric oxide, and NO_2, nitrogen dioxide, are detected)
SO2	sulfur dioxide
HCN	hydrogen cyanide

In our test procedures, Dräger® colorimetric gas analysis tubes are used. These devices are small glass tubes containing one or more chemical indicators/absorbents that change color when a specific gas reacts with

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the chemical inside the tube. The length of the coloration is proportional to the concentration of the gas when a fixed volume of the test atmosphere is drawn through the tube (which is accomplished by a hand pump). These tubes have several distinct advantages over other analytical methods for fire gases under the conditions of this test procedure. They are pre-calibrated; they are relatively simple to operate; there is nothing between the gas of interest and the analysis tube; the results are straightforward and immediate; and this single technique can be used for each of the gases specified (plus several other common gases). Other procedures require more extensive instrumentation with calibration by standard solutions or gases; they introduce additional sampling concerns (which are different for each gas); and no single technique can be used for the six gases specified.

Information is available on each of the Dräger tubes describing the potential interferences for each tube and the range of concentrations over which the tube is calibrated. The stated accuracy of these tubes is in the range of 10-15 percent; however, the combination of sampling errors and analytical uncertainty in other methods could also approach this. In our procedure, we burn several test specimens and take an average of these readings in an effort to minimize the uncertainty in the results.

This standard is intended to measure and describe the properties of materials or products in response to heat and flame under controlled laboratory conditions and is not intended to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions.

TEST PROCEDURE

Specimens were exposed to flaming conditions in the smoke chamber, in accordance with the procedures in ASTM E662. Gas analyses for the species listed below were performed using Dräger® gas detector tubes. Specimens were exposed to flaming conditions for four minutes; then the igniter was extinguished, the specimen was displaced from the radiant heat flux, any excess pressure within the chamber was released, and the analyses were started within one minute. Prior to starting the analyses, a small fan inside the chamber was activated briefly to mix the components.

Gas samples were extracted using the gas analysis tubes from points approximately six inches from the top of the chamber and four inches from either side wall. Although this is not the same location as given in BSS

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7239 (i.e., 12 in. from the ceiling, in the center of the chamber), our sampling location was determined after considerable reflection on the advantages and disadvantages of various sampling schemes using these tubes. It is our belief that there would be no difference in the two sampling locations using our method of specimen exposure and sampling methodology.

Different tubes were drawn simultaneously from two different locations at opposite sides of the chamber in order to reduce the total time required for sampling. For replicate tests, tubes were drawn by a different operator from the other location. The gases more likely to change concentration due to reaction with moisture or soot in the chamber (i.e., HCl, HCN, HF) are drawn first in order to minimize their residence time in the chamber; while CO is sampled last, since its concentration will not change with time.

Table 1 is a listing of the specific gas detector tubes used in this study

Table 1. Identification of Gas Analysis Tubes used

Gas	Draeger Tube No.	Concentration Range, ppm	Number of Strokes
CO	5/c	100 - 700	10
HF	1.5/b	1.5 - 15	20
HCl	50/a	50 - 500	10
NO_x	2/a	2 - 50	10
SO_2	0.5/a	1 - 25	10
HCN	2/a	2 - 30	5

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Results

Specimens submitted by: InstaCote Inc.

Date received: April 3, 1998

Date tested: April 7, 1998

Specimen ID : InstaCote ML-2R Soft TR004 Blue

Description of specimen: Blue InstaCote 4" X 12"

Specimen preparation and mounting method: The specimens were made from a 4" x 12" sheet of blue InstaCote and subjected to the standard conditioning and mounting methods.

Table 2. Test Results with notations
(concentrations in ppm unless otherwise noted)

Test ID	CO	HF	HCl	NO_x	SO_2	HCN
1 Flaming	90	n.d.	1	40	n.d.	5
2 Flaming	100	n.d.	3	30	n.d.	5
Average:	95	n/a	2	35	n/a	5

NOTES:
n. d. = "none detected"

OMEGA POINT LABORATORIES

Project No. 15806-103043
InstaCote Inc.

April 8, 1998
Page ii

Abstract

Specimens submitted by InstaCote Inc. and identified as "InstaCote ML-2R Soft TR004 Blue" were tested in accordance with BSS 7239-88 by the procedures reported herein. Concentrations of the gases CO, HF, HCl, NO_x, SO_2, and HCN were determined .

This report contains a total of six pages.

Test Conducted by:

Sal Romo
Servando Romo
Fire Test Technologist

4/10/98
Date

Reviewed by:

Ernst L Schmidt Jr
Ernst L. Schmidt, Jr.
Manager, Small Scale Testing

4/13/98
Date

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APPENDIX D

HYDROGEN GAS GENERATION CALCULATIONS

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D-1 The Source Term Derivation

According to the SARAH model (HNF-8739, *Hanford Safety Analysis and Risk Assessment Handbook [SARAH]*), 500 and 200 g of equivalent plutonium of 12% ^{240}Pu and ^{241}Am based on 20-year aged has a composition according to Table D-1.

Table D-1. Source Term Derivation.

Isotope	Wt%	Specific activity (Ci/g)	500 g TRU source term mass (g)	500 g TRU source term (Ci)	200 g TRU source term mass (g)	200 g TRU source term (Ci)
^{238}Pu	0.08	1.71 E+01	4.00 E-01	6.84 E+00	1.60 E-01	2.74 E+00
^{239}Pu	83.95	6.20 E-02	4.20 E+02	2.60 E+01	1.68 E+02	1.04 E+01
^{240}Pu	12.97	2.27 E-01	6.49 E+01	1.47 E+01	2.59 E+01	5.89 E+00
^{241}Pu	1.1	1.03 E+02	5.50 E+00	5.67 E+02	2.20 E+00	2.27 E+02
^{242}Pu	0.03	3.95 E-03	1.50 E-01	5.93 E-04	6.00 E-02	2.37 E-04
^{241}Am	1.75	3.43 E+00	8.75 E+00	3.00 E+01	3.50 E+00	1.20 E+01
Total	100		5.00 E+02	6.44 E+02	2.00 E+02	2.58 E+02

TRU = transuranic.

D.2 Volume (External) of 208 L (55-gal) Drum (from Myers Container[1] Corporation)

The volume of polyurea is determined by subtracting the volume of the 208 L (55-gal) drum from the volume of the same drum with the polyurea coating. A 500 mil layer of polyurea is equivalent to 0.5 in.

Height, h = 33.75 in.

Diameter, d = 24 in.

$$V_{55-gal} = \left(\pi \frac{d^2}{4}\right) \times h$$

$$V_{55-gal} = \left(\pi \frac{[24]^2}{4}\right) \times 33.75$$

$$V_{55-gal} = 15{,}268 \ in^3$$

$$V_{55-gal} = 0.250 \ m^3$$

[1] Myers Container is a registered trademark of Myers Container Corporation.

D.3 Volume (External) of 208 L (55-gal) Drum with Polyurea Coating (from Myers Container Corporation)

The polyurea coating is assumed to 0.5 in. thick, fully covering the entire drum.

h = 34.75 in.

d = 25 in.

$$V_{55-gal-coat} = \left(\pi \frac{d^2}{4}\right) \times h$$

$$V_{55-gal-coat} = \left(\pi \frac{[25]^2}{4}\right) \times 34.75$$

$$V_{55-gal-coat} = 17{,}057.9 in^3$$

$$V_{55-gal-coat} = 0.280 m^3$$

D.4 Density of Polyurea

Polyurea can be applied at multiple formulations. Thus, the density used for these calculations is approximated according to the data presented on the test sample of material in InstaCote SE FR tests (Appendix B). The density of the Envirolast AR425 is 1102 kg/m^3 (Appendix A), so using the InstaCote is conservative.

Width of sample = 24 in.

Length of sample = 24 ft = 288 in.

Thickness of sample = 0.516 in.

Mass of sample = 155.5 lb

$$density_{polyurea} = M_{polyurea} \div V_{polyurea}$$

$$V_{polyurea} = l \times w \times h$$

$$V_{polyurea} = 288 inches \times 24 inches \times 0.516 inches$$

$$V_{polyurea} = 3566.6 in^3$$

$$density_{polyurea} = 155.5 lbs \div 3566.6 in^3$$

$$density_{polyurea} = 0.044 lbs / in^3$$

$$density_{polyurea} = 1218 kg / m^3$$

D.5 Volume and Mass of Polyurea after It Is Applied to the Drum

$$V_{polyurea} = V_{55-gal-coat} - V_{55-gal}$$
$$V_{polyurea} = 0.280m^3 - 0.250m^3$$
$$V_{polyurea} = 0.030m^3$$
$$M_{polyurea} = V_{polyurea} \times density_{polyurea}$$
$$M_{polyurea} = 0.030m^3 \times 1218kg/m^3$$
$$M_{polyurea} = 36.54kg$$

D.6 Volume of 322 L (85-gal) Drum (Myers Container Corporation)

The scenario for these calculations assumes the polyurea-coated 208 L (55-gal) drum is placed in a 322 L (85-gal) overpack. The reason or need to overpack the 208 L (55-gal) drum is a facility operations decision and does not impact these calculations.

$$V_{85} = 0.322\ m^3$$

D.7 Void of322 L (85-gal) Drum

The 208 L (55-gal) drum is centered in the 322 L (85-gal) drum with wooden wedges located at the top of the drum. These wedges are assumed to be made of Douglas fir and weigh 1 kg.

$$M_{wedges} = 1kg$$
$$density_{douglasfir} = 560.6kg/m^3 \text{(Douglas fir : Pocket Reference, 3rd Edition)}$$

$$V_{wedges} = M_{wedges} \div density_{douglasfir}$$
$$V_{wedges} = 1kg \div 560.6kg/m^3$$
$$V_{wedges} = .0018m^3$$
$$V_{void-85} = V_{85} - V_{55-gal-coat} - V_{wedges}$$
$$V_{void-85} = 0.322m^3 - 0.280m^3 - 0.0018m^3$$
$$V_{void-85} = 0.0402m^3$$

D.8 Weight Percent of 322 L (85-gal) Drum

The recommended payload weight limit for a 322 L (85-gal) drum is:

(435 kg – 35.4 kg) = 399.6 kg (881 lb),

where:

85-gal gross weight is 435 kg (959.0 lb),
85-gal tare weight is 35.4 kg (78.0 lb).

The wood wedges are 1 kg, and the polyurea is estimated to weigh 36.54 kg (80.6 lb). Therefore, the contents of the 208 L (55-gal) drum cannot weigh more than:

399.6 kg - 1 kg - 36.54 kg = 362.06 kg, or
881 lb – 2.2 lb – 80.6 lb = 798.2 lb

The weight fractions are described in Table D-2.

Table D-2. Weight Fraction of the 322 L (85-gal) Overpack for Input to Radcalc.

	Weight (kg)	Weight (%)	Weight % composition
$M_{55\text{-gal}}$	362.06	90.6	USER
M_{wood}	1.0	0.25	Wooden shims (cellulose)
$M_{polyurea}$	36.54	9.14	Polyethylene (HDPE Marlex*-50)
M_{waste}	399.6		

HDPE = high-density polyethylene.

*Marlex is a registered trademark of the Phillips Petroleum Company, Woodlands, Texas.

DTS-SQA-009.1, 2005, *Radcalc Volume I: User's Manual*, Rev. 0, Duratek Technical Services, Richland, Washington.

D.9 Waste Percent, Waste Volume, and Void Volume Without Polyurea

$$V_{55-gal} = 0.250m^3$$
$$V_{wood} = 0.0018m^3$$
$$V_{85} = 0.322m^3$$

$$V_{waste} = V_{55-gal} + V_{wood}$$
$$V_{waste} = 0.250m^3 + 0.0018m^3$$
$$V_{waste} = 0.252m^3$$

$$V_{void} = V_{85} - V_{wood} - V_{55-gal}$$
$$V_{void} = 0.322m^3 - 0.0018m^3 - 0.250m^3$$
$$V_{void} = 0.0702m^3$$

Table D-3 shows the weight fractions without polyurea.

Table D-3. Weight Fraction of the 322 L (85-gal) Overpack Without Polyurea for Input to Radcalc.

	Weight (kg)	Weight (%)	Weight % composition
$M_{55\text{-gal}}$	362.06	99.7	USER
M_{wood}	1.0	0.3	Wooden shims (cellulose)
$M_{polyurea}$	0	0	Polyethylene (HDPE Marlex*-50)
M_{waste}	363.06		

HDPE = high-density polyethylene.

*Marlex is a registered trademark of the Phillips Petroleum Company, Woodlands, Texas.

DTS-SQA-009.1, 2005, *Radcalc Volume I: User's Manual*, Rev. 0, Duratek Technical Services, Richland, Washington.

D.10 References

DTS-SQA-009.1, 2005, *Radcalc Volume I: User's Manual*, Rev. 0, Duratek Technical Services, Richland, Washington.

HNF-8739, 2004, *Hanford Safety Analysis and Risk Assessment Handbook (SARAH)*, Rev. 1, Fluor Hanford, Inc., Richland, Washington.

Sequoia, 2006, *Pocket Reference* (Douglas fir), 3rd Edition, 18th Printing, Sequoia Publishing, Inc., Littleton, Colorado.

D.11 Radcalc Output Files

D.11.1 500 g Source Term with Polyurea

Performed By: Terry Vail
Checked By: John Woodbury

===================================== Input Information =====================================

Source Data:

Isotope	Ci	Bq	Gm
Pu-238	6.840E+00	2.531E+11	3.994E-01
Pu-239	2.600E+01	9.620E+11	4.192E+02
Pu-240	1.470E+01	5.439E+11	6.478E+01
Pu-241	5.670E+02	2.098E+13	5.505E+00
Pu-242	5.930E-04	2.194E+07	1.500E-01
Am-241	3.000E+01	1.110E+12	8.753E+00

Container Data:

Container Void Volume:	0.0402	m^3
Container Mass:	35.4	kg
Gamma Abs Curve:	85-Gal Drum	

Waste Data:

Waste Form:	Normal	
Waste State:	Solid	
Waste Volume:	0.282	m^3
Waste Mass:	399.6	kg
Mass of beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Waste Void Volume:	0	m^3

Decay Time Data:

Date to begin source decay:	1/1/1979
Date container sealed:	2/15/2007
Date container opened:	5/15/2012

G Value Materials Data:

Wt. Fraction	G Alpha	G Beta	G Gamma	Material Name
9.14	0	0	3.8	Polyethylene (HDPE Marlex-50)
90.6	0	0	0	USER
0.25	0	0	3.2	Cellulose

G Value Data:

G Alpha	G Beta	G Gamma
0	0	0.3554

G values calculated from the list of materials (above).

Comments:
Gas generated by a 55 gallon drum with 500 g of 12% TRU fully coated with polyurea and placed in a 85-gallon overpack.

================================== Calculated Results ==================================

Decay Heat:

Heat Generated on Start Date:	2.514	W
Heat Generated on Seal Date:	2.865	W
Heat Generated on Open Date:	2.88	W

Hydrogen Gas:

H2 Concentration:	1.9	%	
H2 Moles :	0.03536	moles	
H2 Volume :	792.6	cm^3	(0 C, 101.325 kPa)
H2 Rate on Seal Date:	0.01709	cm^3/hr	(0 C, 101.325 kPa)
H2 Rate On Open Date:	0.01737	cm^3/hr	(0 C, 101.325 kPa)

Helium Gas:

He Concentration:	0.049	%	
He Moles :	0.000902	moles	
He Volume :	20.22	cm^3	(0 C, 101.325 kPa)
He Rate On Seal Date:	0.0004383	cm^3/hr	(0 C, 101.325 kPa)
He Rate On Open Date:	0.0004408	cm^3/hr	(0 C, 101.325 kPa)

Pressure On Open Date:

Partial Pressure (H2):	1.958	kPa	
Partial Pressure (He):	0.04995	kPa	
Partial Pressure (O2):	0.9791	kPa	(if H20 present in waste)
Total Pressure (H2 + He + Air):	103.3	kPa	
Total Pressure (H2 + He + O2 + Air):	104.3	kPa	(if H20 present in waste)

Transportation:
Note: Calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	8330000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	870200000	ALECs	(Number of ALECs)

This package is not exempt from the HMR.

Effective A2s for Mixture:	0.06977	Ci

Type Determination:

Type:	B		(A2s > 1.0)
A2 Limit Fraction:	3366	A2s	(Number of A2s)

Limited Quantity Determination:

Limited Quantity:	No		(Activity > 0.001 A2)
Activity:	3366	A2	
	260.8	Ci	
	9.651	TBq	
U-235 Activity:	0.3331	gm	

The user must check ensure that all other requirements for LQ in 49 CFR 173.421 are met.

LSA Determination:

LSA-I:	No		(A2s > 30 x rad limits, and not fissile excepted)
LSA-II:	No		(A2s/gm > 0.0001)
LSA-III:	No		(A2s/gm > 0.002)
Specific Activity:	0.008423	A2/gm	
	0.0006527	Ci/gm	

The user must check ensure that all other requirements for LSA in 49 CFR 173.403 and 49 CFR 173.427 are met.

HRCQ Determination:

HRCQ:	Yes		(A2s > 3000)
A2 Limit Fraction:	3366	A2s	
Activity:	260.8	Ci	
	9.651	TBq	

Fissile Excepted Determination:

Fissile Excepted:	No		Package is fissile
Fissile Quantity:	420.6	gm	
Beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm	
Solid Non-Fissile Quantity:	434600	gm	
Total Uranium Quantity:	0.6003	gm	
U-233 Quantity:	2.053E-06	gm	
U-235 Quantity:	0.3331	gm	
Uranium Enrichment:	55.49	%	
Total Plutonium Quantity:	485.4	gm	
Pu-239 Quantity:	418.9	gm	
Pu-241 Quantity:	1.422	gm	

Container Category Determination:			
Container Category:	I		
TRU Waste Determination:			
TRU Waste:	Yes		(TRU activity > 100 nCi/gm)
TRU Activity:	221200	nCi/g	
WIPP Quantities:			
FGE Value:	424.1		
PE-Ci Value:	90.78		
Reportable Quantity Determination:			
Reportable Quantity:	Yes		(RQs >= 1.0)
RQ Limit Fraction:	9013	RQs	(Number of RQs)
Dose-Equivalent Curies:			
Total ICRP-71/72 DE-Ci:	83.84		
Total FGR-11 DE-Ci:	92.01		

Source at the Start of Seal Time:

Isotope	Ci	Bq	Gm
Hg-206	9.543E-19	3.531E-08	8.520E-27
Tl-206	6.708E-17	2.482E-06	3.086E-25
Tl-207	5.107E-11	1.889E+00	2.681E-19
Tl-208	1.388E-15	5.137E-05	4.692E-24
Tl-209	3.605E-13	1.334E-02	8.814E-22
Tl-210	5.638E-14	2.086E-03	8.185E-23
Pb-209	1.669E-11	6.175E-01	3.620E-18
Pb-210	5.023E-11	1.858E+00	6.579E-13
Pb-211	5.121E-11	1.895E+00	2.074E-18
Pb-212	3.863E-15	1.429E-04	2.781E-21
Pb-214	2.684E-10	9.931E+00	8.187E-18
Bi-210	5.009E-11	1.853E+00	4.038E-16
Bi-211	5.121E-11	1.895E+00	1.247E-19
Bi-212	3.863E-15	1.429E-04	2.637E-22
Bi-213	1.669E-11	6.175E-01	8.618E-19
Bi-214	2.685E-10	9.933E+00	6.080E-18
Bi-215	4.161E-17	1.540E-06	3.521E-25
Po-210	4.658E-11	1.724E+00	1.037E-14
Po-211	1.398E-13	5.172E-03	1.349E-24
Po-212	2.474E-15	9.155E-05	1.395E-32
Po-213	1.633E-11	6.042E-01	1.295E-27
Po-214	2.684E-10	9.931E+00	8.400E-25
Po-215	5.121E-11	1.895E+00	1.737E-24
Po-216	3.864E-15	1.430E-04	1.073E-26
Po-218	2.685E-10	9.933E+00	9.494E-19
At-215	2.048E-16	7.579E-06	3.903E-31
At-217	1.669E-11	6.175E-01	1.037E-23
At-218	5.369E-14	1.987E-03	1.660E-24
At-219	4.290E-17	1.587E-06	4.497E-26
Rn-217	2.003E-15	7.410E-05	2.080E-29
Rn-218	5.369E-17	1.987E-06	3.631E-29
Rn-219	5.121E-11	1.895E+00	3.936E-21
Rn-220	3.864E-15	1.430E-04	4.190E-24
Rn-222	2.685E-10	9.933E+00	1.746E-15
Fr-221	1.669E-11	6.175E-01	9.613E-20
Fr-223	7.150E-13	2.646E-02	1.849E-20
Ra-223	5.121E-11	1.895E+00	9.997E-16
Ra-224	3.864E-15	1.430E-04	2.400E-20
Ra-225	1.676E-11	6.202E-01	4.276E-16
Ra-226	2.689E-10	9.949E+00	2.720E-10
Ra-228	4.905E-15	1.815E-04	1.799E-17
Ac-225	1.669E-11	6.175E-01	2.876E-16
Ac-227	5.181E-11	1.917E+00	7.164E-13
Ac-228	4.904E-15	1.815E-04	2.195E-21
Th-227	5.072E-11	1.877E+00	1.651E-15
Th-228	3.869E-15	1.432E-04	4.721E-18

Th-229	1.687E-11	6.243E-01	7.934E-11
Th-230	6.522E-08	2.413E+03	3.164E-06
Th-231	7.197E-07	2.663E+04	1.354E-12
Th-232	8.481E-15	3.138E-04	7.734E-08
Th-234	2.578E-12	9.540E-02	1.114E-16
Pa-231	2.141E-10	7.921E+00	4.533E-09
Pa-233	3.423E-04	1.266E+07	1.649E-08
Pa-234	3.352E-15	1.240E-04	1.677E-21
Pa-234m	2.578E-12	9.540E-02	3.755E-21
U-233	1.977E-08	7.317E+02	2.053E-06
U-234	4.866E-04	1.800E+07	7.827E-02
U-235	7.198E-07	2.663E+04	3.331E-01
U-235m	2.598E+01	9.611E+11	8.443E-07
U-236	1.222E-05	4.521E+05	1.889E-01
U-237	3.592E-03	1.329E+08	4.402E-08
U-238	2.587E-12	9.572E-02	7.697E-06
Np-237	3.437E-04	1.272E+07	4.877E-01
Pu-238	5.477E+00	2.026E+11	3.198E-01
Pu-239	2.598E+01	9.612E+11	4.189E+02
Pu-240	1.466E+01	5.423E+11	6.459E+01
Pu-241	1.464E+02	5.418E+12	1.422E+00
Pu-242	5.930E-04	2.194E+07	1.500E-01
Am-241	4.230E+01	1.565E+12	1.234E+01
Total Activity:	2.608E+02	9.651E+12	
w/o Daughters:	2.349E+02	8.690E+12	

Shipping Papers and Labels:

	Isotope	Number of A2s	Fraction of A2s	Cumulative A2s	Cumulative Fraction of A2s
*	Am-241	1567	0.4654	1567	0.4654
*	Pu-239	962.2	0.2859	2529	0.7513
*	Pu-240	542.8	0.1613	3072	0.9125
*	Pu-238	202.8	0.06026	3274	0.9728
	Pu-241	91.53	0.02719	3366	1

* Contains 95% of the total A2s and must be included per 49 CFR 173.433.
Radionuclides comprising less than 0.1% of the total A2s are not shown in the list.

D.11.2 500 g Source Term Without Polyurea

Performed By: Terry Vail
Checked By: John Woodbury

==================================== Input Information ====================================

Source Data:

Isotope	Ci	Bq	Gm
Pu-238	6.840E+00	2.531E+11	3.994E-01
Pu-239	2.600E+01	9.620E+11	4.192E+02
Pu-240	1.470E+01	5.439E+11	6.478E+01
Pu-241	5.670E+02	2.098E+13	5.505E+00
Pu-242	5.930E-04	2.194E+07	1.500E-01
Am-241	3.000E+01	1.110E+12	8.753E+00

Container Data:

Container Void Volume:	0.0702	m^3
Container Mass:	35.4	kg
Gamma Abs Curve:	85-Gal Drum	

Waste Data:

Waste Form:	Normal	
Waste State:	Solid	
Waste Volume:	0.252	m^3
Waste Mass:	363.1	kg
Mass of beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Waste Void Volume:	0	m^3

Decay Time Data:

Date to begin source decay:	1/1/1979
Date container sealed:	2/15/2007
Date container opened:	5/15/2012

G Value Materials Data:

Wt. Fraction	G Alpha	G Beta	G Gamma	Material Name
99.65	0	0	0	USER
0.25	0	0	3.2	Cellulose

G Value Data:

G Alpha	G Beta	G Gamma
0	0	0.008008

G values calculated from the list of materials (above).

Comments:
Gas generated by a 55 gallon drum with 500 g of 12% TRU without polyurea and placed in a 85-gallon overpack.

==================================== Calculated Results ====================================

Decay Heat:

Heat Generated on Start Date:	2.514	W
Heat Generated on Seal Date:	2.865	W
Heat Generated on Open Date:	2.88	W

Hydrogen Gas:

H2 Concentration:	0.026	%	
H2 Moles :	0.000802	moles	
H2 Volume :	17.98	cm^3	(0 C, 101.325 kPa)
H2 Rate on Seal Date:	0.0003876	cm^3/hr	(0 C, 101.325 kPa)
H2 Rate On Open Date:	0.0003938	cm^3/hr	(0 C, 101.325 kPa)

Helium Gas:

He Concentration:	0.029	%
He Moles :	0.000902	moles

He Volume :	20.22	cm^3	(0 C, 101.325 kPa)
He Rate On Seal Date:	0.0004383	cm^3/hr	(0 C, 101.325 kPa)
He Rate On Open Date:	0.0004408	cm^3/hr	(0 C, 101.325 kPa)

Pressure On Open Date:

Partial Pressure (H2):	0.02593	kPa	
Partial Pressure (He):	0.02916	kPa	
Partial Pressure (O2):	0.01297	kPa	(if H20 present in waste)
Total Pressure (H2 + He + Air):	101.4	kPa	
Total Pressure (H2 + He + O2 + Air):	101.4	kPa	(if H20 present in waste)

Transportation:
Note: Calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	9168000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	870200000	ALECs	(Number of ALECs)

This package is not exempt from the HMR.

Effective A2s for Mixture:	0.06977	Ci

Type Determination:

Type:	B		(A2s > 1.0)
A2 Limit Fraction:	3366	A2s	(Number of A2s)

Limited Quantity Determination:

Limited Quantity:	No		(Activity > 0.001 A2)
Activity:	3366	A2	
	260.8	Ci	
	9.651	TBq	
U-235 Activity:	0.3331	gm	

The user must check ensure that all other requirements for LQ in 49 CFR 173.421 are met.

LSA Determination:

LSA-I:	No		(A2s > 30 x rad limits, and not fissile excepted)
LSA-II:	No		(A2s/gm > 0.0001)
LSA-III:	No		(A2s/gm > 0.002)
Specific Activity:	0.009271	A2/gm	
	0.0007184	Ci/gm	

The user must check ensure that all other requirements for LSA in 49 CFR 173.403 and 49 CFR 173.427 are met.

HRCQ Determination:

HRCQ:	Yes		(A2s > 3000)
A2 Limit Fraction:	3366	A2s	
Activity:	260.8	Ci	
	9.651	TBq	

Fissile Excepted Determination:

Fissile Excepted:	No		Package is fissile
Fissile Quantity:	420.6	gm	
Beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm	
Solid Non-Fissile Quantity:	398000	gm	
Total Uranium Quantity:	0.6003	gm	
U-233 Quantity:	2.053E-06	gm	
U-235 Quantity:	0.3331	gm	
Uranium Enrichment:	55.49	%	
Total Plutonium Quantity:	485.4	gm	
Pu-239 Quantity:	418.9	gm	
Pu-241 Quantity:	1.422	gm	

Container Category Determination:

Container Category:	I

TRU Waste Determination:

TRU Waste:	Yes		(TRU activity > 100 nCi/gm)
TRU Activity:	243500	nCi/g	

WIPP Quantities:

FGE Value:	424.1
PE-Ci Value:	90.78

Reportable Quantity Determination:

Reportable Quantity:	Yes		(RQs >= 1.0)
RQ Limit Fraction:	9013	RQs	(Number of RQs)

Dose-Equivalent Curies:

Total ICRP-71/72 DE-Ci:	83.84
Total FGR-11 DE-Ci:	92.01

Source at the Start of Seal Time:

Isotope	Ci	Bq	Gm
Hg-206	9.543E-19	3.531E-08	8.520E-27
Tl-206	6.708E-17	2.482E-06	3.086E-25
Tl-207	5.107E-11	1.889E+00	2.681E-19
Tl-208	1.388E-15	5.137E-05	4.692E-24
Tl-209	3.605E-13	1.334E-02	8.814E-22
Tl-210	5.638E-14	2.086E-03	8.185E-23
Pb-209	1.669E-11	6.175E-01	3.620E-18
Pb-210	5.023E-11	1.858E+00	6.579E-13
Pb-211	5.121E-11	1.895E+00	2.074E-18
Pb-212	3.863E-15	1.429E-04	2.781E-21
Pb-214	2.684E-10	9.931E+00	8.187E-18
Bi-210	5.009E-11	1.853E+00	4.038E-16
Bi-211	5.121E-11	1.895E+00	1.247E-19
Bi-212	3.863E-15	1.429E-04	2.637E-22
Bi-213	1.669E-11	6.175E-01	8.618E-19
Bi-214	2.685E-10	9.933E+00	6.080E-18
Bi-215	4.161E-17	1.540E-06	3.521E-25
Po-210	4.658E-11	1.724E+00	1.037E-14
Po-211	1.398E-13	5.172E-03	1.349E-24
Po-212	2.474E-15	9.155E-05	1.395E-32
Po-213	1.633E-11	6.042E-01	1.295E-27
Po-214	2.684E-10	9.931E+00	8.400E-25
Po-215	5.121E-11	1.895E+00	1.737E-24
Po-216	3.864E-15	1.430E-04	1.073E-26
Po-218	2.685E-10	9.933E+00	9.494E-19
At-215	2.048E-16	7.579E-06	3.903E-31
At-217	1.669E-11	6.175E-01	1.037E-23
At-218	5.369E-14	1.987E-03	1.660E-24
At-219	4.290E-17	1.587E-06	4.497E-26
Rn-217	2.003E-15	7.410E-05	2.080E-29
Rn-218	5.369E-17	1.987E-06	3.631E-29
Rn-219	5.121E-11	1.895E+00	3.936E-21
Rn-220	3.864E-15	1.430E-04	4.190E-24
Rn-222	2.685E-10	9.933E+00	1.746E-15
Fr-221	1.669E-11	6.175E-01	9.613E-20
Fr-223	7.150E-13	2.646E-02	1.849E-20
Ra-223	5.121E-11	1.895E+00	9.997E-16
Ra-224	3.864E-15	1.430E-04	2.400E-20
Ra-225	1.676E-11	6.202E-01	4.276E-16
Ra-226	2.689E-10	9.949E+00	2.720E-10
Ra-228	4.905E-15	1.815E-04	1.799E-17
Ac-225	1.669E-11	6.175E-01	2.876E-16
Ac-227	5.181E-11	1.917E+00	7.164E-13
Ac-228	4.904E-15	1.815E-04	2.195E-21
Th-227	5.072E-11	1.877E+00	1.651E-15
Th-228	3.869E-15	1.432E-04	4.721E-18
Th-229	1.687E-11	6.243E-01	7.934E-11
Th-230	6.522E-08	2.413E+03	3.164E-06
Th-231	7.197E-07	2.663E+04	1.354E-12
Th-232	8.481E-15	3.138E-04	7.734E-08

Th-234	2.578E-12	9.540E-02	1.114E-16
Pa-231	2.141E-10	7.921E+00	4.533E-09
Pa-233	3.423E-04	1.266E+07	1.649E-08
Pa-234	3.352E-15	1.240E-04	1.677E-21
Pa-234m	2.578E-12	9.540E-02	3.755E-21
U-233	1.977E-08	7.317E+02	2.053E-06
U-234	4.866E-04	1.800E+07	7.827E-02
U-235	7.198E-07	2.663E+04	3.331E-01
U-235m	2.598E+01	9.611E+11	8.443E-07
U-236	1.222E-05	4.521E+05	1.889E-01
U-237	3.592E-03	1.329E+08	4.402E-08
U-238	2.587E-12	9.572E-02	7.697E-06
Np-237	3.437E-04	1.272E+07	4.877E-01
Pu-238	5.477E+00	2.026E+11	3.198E-01
Pu-239	2.598E+01	9.612E+11	4.189E+02
Pu-240	1.466E+01	5.423E+11	6.459E+01
Pu-241	1.464E+02	5.418E+12	1.422E+00
Pu-242	5.930E-04	2.194E+07	1.500E-01
Am-241	4.230E+01	1.565E+12	1.234E+01
Total Activity:	2.608E+02	9.651E+12	
w/o Daughters:	2.349E+02	8.690E+12	

Shipping Papers and Labels:

	Isotope	Number of A2s	Fraction of A2s	Cumulative A2s	Cumulative Fraction of A2s
*	Am-241	1567	0.4654	1567	0.4654
*	Pu-239	962.2	0.2859	2529	0.7513
*	Pu-240	542.8	0.1613	3072	0.9125
*	Pu-238	202.8	0.06026	3274	0.9728
	Pu-241	91.53	0.02719	3366	1

* Contains 95% of the total A2s and must be included per 49 CFR 173.433.
Radionuclides comprising less than 0.1% of the total A2s are not shown in the list.

D.11.3 200 g Source Term with Polyurea

Performed By: Terry Vail
Checked By: John Woodbury

===================================== Input Information =====================================

Source Data:

Isotope	Ci	Bq	Gm
Pu-238	2.740E+00	1.014E+11	1.600E-01
Pu-239	1.040E+01	3.848E+11	1.677E+02
Pu-240	5.890E+00	2.179E+11	2.596E+01
Pu-241	2.270E+02	8.399E+12	2.204E+00
Pu-242	2.370E-04	8.769E+06	5.994E-02
Am-241	1.200E+01	4.440E+11	3.501E+00

Container Data:

Container Void Volume:	0.0402	m^3
Container Mass:	35.4	kg
Gamma Abs Curve:	85-Gal Drum	

Waste Data:

Waste Form:	Normal	
Waste State:	Solid	
Waste Volume:	0.282	m^3
Waste Mass:	399.6	kg
Mass of beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Waste Void Volume:	0	m^3

Decay Time Data:

Date to begin source decay:	1/1/1979
Date container sealed:	2/15/2007
Date container opened:	5/15/2012

G Value Materials Data:

Wt. Fraction	G Alpha	G Beta	G Gamma	Material Name
9.14	0	0	3.8	Polyethylene (HDPE Marlex-50)
90.6	0	0	0	USER
0.25	0	0	3.2	Cellulose

G Value Data:

G Alpha	G Beta	G Gamma
0	0	0.3554

G values calculated from the list of materials (above).

Comments:
Gas generated by a 55 gallon drum with 200 g of 12% TRU fully coated with polyurea and placed in a 85-gallon overpack.

================================== Calculated Results ==================================

Decay Heat:

Heat Generated on Start Date:	1.006	W
Heat Generated on Seal Date:	1.146	W
Heat Generated on Open Date:	1.153	W

Hydrogen Gas:

H2 Concentration:	0.78	%	
H2 Moles :	0.01415	moles	
H2 Volume :	317.2	cm^3	(0 C, 101.325 kPa)
H2 Rate on Seal Date:	0.006838	cm^3/hr	(0 C, 101.325 kPa)
H2 Rate On Open Date:	0.006949	cm^3/hr	(0 C, 101.325 kPa)

Helium Gas:

He Concentration:	0.02	%

He Moles :	0.000361	moles	
He Volume :	8.091	cm^3	(0 C, 101.325 kPa)
He Rate On Seal Date:	0.0001754	cm^3/hr	(0 C, 101.325 kPa)
He Rate On Open Date:	0.0001764	cm^3/hr	(0 C, 101.325 kPa)

Pressure On Open Date:

Partial Pressure (H2):	0.793	kPa	
Partial Pressure (He):	0.02023	kPa	
Partial Pressure (O2):	0.3965	kPa	(if H20 present in waste)
Total Pressure (H2 + He + Air):	102.1	kPa	
Total Pressure (H2 + He + O2 + Air):	102.5	kPa	(if H20 present in waste)

Transportation:
Note: Calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	3334000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	348500000	ALECs	(Number of ALECs)

This package is not exempt from the HMR.

Effective A2s for Mixture:	0.06979	Ci

Type Determination:

Type:	B		(A2s > 1.0)
A2 Limit Fraction:	1347	A2s	(Number of A2s)

Limited Quantity Determination:

Limited Quantity:	No		(Activity > 0.001 A2)
Activity:	1347	A2	
	104.4	Ci	
	3.863	TBq	
U-235 Activity:	0.1332	gm	

The user must check ensure that all other requirements for LQ in 49 CFR 173.421 are met.

LSA Determination:

LSA-I:	No		(Fissile excepted, but A2s > 30 x rad limits)
LSA-II:	No		(A2s/gm > 0.0001)
LSA-III:	No		(A2s/gm > 0.002)
Specific Activity:	0.003371	A2/gm	
	0.0002613	Ci/gm	

The user must check ensure that all other requirements for LSA in 49 CFR 173.403 and 49 CFR 173.427 are met.

HRCQ Determination:

HRCQ:	No	
A2 Limit Fraction:	1347	A2s
Activity:	104.4	Ci
	3.863	TBq

Fissile Excepted Determination:

Fissile Excepted: Yes (Fissile isotopes <= 180 grams, solid non-fissile material > 3.365E+05 grams)

Fissile Quantity:	168.3	gm
Beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm
Solid Non-Fissile Quantity:	434800	gm
Total Uranium Quantity:	0.2403	gm
U-233 Quantity:	8.212E-07	gm
U-235 Quantity:	0.1332	gm
Uranium Enrichment:	55.45	%
Total Plutonium Quantity:	194.2	gm
Pu-239 Quantity:	167.6	gm
Pu-241 Quantity:	0.5693	gm

Container Category Determination:

Container Category: II

TRU Waste Determination:

TRU Waste:	Yes		(TRU activity > 100 nCi/gm)
TRU Activity:	88540	nCi/g	

WIPP Quantities:

FGE Value:	169.7
PE-Ci Value:	36.33

Reportable Quantity Determination:

Reportable Quantity:	Yes		(RQs >= 1.0)
RQ Limit Fraction:	3607	RQs	(Number of RQs)

Dose-Equivalent Curies:

Total ICRP-71/72 DE-Ci:	33.55
Total FGR-11 DE-Ci:	36.82

Source at the Start of Seal Time:

Isotope	Ci	Bq	Gm
Hg-206	3.823E-19	1.414E-08	3.413E-27
Tl-206	2.687E-17	9.942E-07	1.236E-25
Tl-207	2.043E-11	7.558E-01	1.073E-19
Tl-208	5.563E-16	2.058E-05	1.880E-24
Tl-209	1.442E-13	5.335E-03	3.526E-22
Tl-210	2.258E-14	8.356E-04	3.279E-23
Pb-209	6.676E-12	2.470E-01	1.448E-18
Pb-210	2.012E-11	7.444E-01	2.635E-13
Pb-211	2.048E-11	7.578E-01	8.297E-19
Pb-212	1.548E-15	5.727E-05	1.114E-21
Pb-214	1.075E-10	3.978E+00	3.280E-18
Bi-210	2.007E-11	7.425E-01	1.618E-16
Bi-211	2.048E-11	7.578E-01	4.987E-20
Bi-212	1.548E-15	5.727E-05	1.057E-22
Bi-213	6.676E-12	2.470E-01	3.448E-19
Bi-214	1.075E-10	3.979E+00	2.436E-18
Bi-215	1.665E-17	6.159E-07	1.408E-25
Po-210	1.866E-11	6.904E-01	4.153E-15
Po-211	5.592E-14	2.069E-03	5.396E-25
Po-212	9.914E-16	3.668E-05	5.589E-33
Po-213	6.533E-12	2.417E-01	5.180E-28
Po-214	1.075E-10	3.978E+00	3.365E-25
Po-215	2.048E-11	7.579E-01	6.948E-25
Po-216	1.548E-15	5.728E-05	4.298E-27
Po-218	1.075E-10	3.979E+00	3.803E-19
At-215	8.193E-17	3.031E-06	1.561E-31
At-217	6.677E-12	2.470E-01	4.148E-24
At-218	2.151E-14	7.958E-04	6.650E-25
At-219	1.716E-17	6.349E-07	1.799E-26
Rn-217	8.012E-16	2.965E-05	8.322E-30
Rn-218	2.151E-17	7.958E-07	1.455E-29
Rn-219	2.048E-11	7.579E-01	1.575E-21
Rn-220	1.548E-15	5.728E-05	1.679E-24
Rn-222	1.075E-10	3.979E+00	6.994E-16
Fr-221	6.677E-12	2.470E-01	3.846E-20
Fr-223	2.860E-13	1.058E-02	7.395E-21
Ra-223	2.048E-11	7.579E-01	3.999E-16
Ra-224	1.548E-15	5.728E-05	9.615E-21
Ra-225	6.706E-12	2.481E-01	1.710E-16
Ra-226	1.077E-10	3.985E+00	1.090E-10
Ra-228	1.965E-15	7.271E-05	7.208E-18
Ac-225	6.677E-12	2.470E-01	1.151E-16
Ac-227	2.073E-11	7.668E-01	2.866E-13
Ac-228	1.965E-15	7.270E-05	8.793E-22
Th-227	2.029E-11	7.507E-01	6.603E-16
Th-228	1.550E-15	5.736E-05	1.892E-18
Th-229	6.750E-12	2.497E-01	3.174E-11
Th-230	2.613E-08	9.667E+02	1.268E-06

Th-231	2.879E-07	1.065E+04	5.417E-13
Th-232	3.398E-15	1.257E-04	3.099E-08
Th-234	1.030E-12	3.813E-02	4.451E-17
Pa-231	8.564E-11	3.169E+00	1.813E-09
Pa-233	1.369E-04	5.066E+06	6.598E-09
Pa-234	1.340E-15	4.956E-05	6.703E-22
Pa-234m	1.030E-12	3.813E-02	1.501E-21
U-233	7.911E-09	2.927E+02	8.212E-07
U-234	1.949E-04	7.212E+06	3.135E-02
U-235	2.879E-07	1.065E+04	1.332E-01
U-235m	1.039E+01	3.844E+11	3.377E-07
U-236	4.896E-06	1.812E+05	7.570E-02
U-237	1.438E-03	5.322E+07	1.762E-08
U-238	1.034E-12	3.826E-02	3.076E-06
Np-237	1.375E-04	5.088E+06	1.951E-01
Pu-238	2.194E+00	8.117E+10	1.281E-01
Pu-239	1.039E+01	3.845E+11	1.676E+02
Pu-240	5.873E+00	2.173E+11	2.588E+01
Pu-241	5.863E+01	2.169E+12	5.693E-01
Pu-242	2.370E-04	8.769E+06	5.993E-02
Am-241	1.692E+01	6.262E+11	4.938E+00
Total Activity:	1.044E+02	3.863E+12	
w/o Daughters:	9.401E+01	3.478E+12	

Shipping Papers and Labels:

	Isotope	Number of A2s	Fraction of A2s	Cumulative A2s	Cumulative Fraction of A2s
*	Am-241	626.8	0.4653	626.8	0.4653
*	Pu-239	384.9	0.2857	1012	0.751
*	Pu-240	217.5	0.1615	1229	0.9125
*	Pu-238	81.26	0.06032	1310	0.9728
	Pu-241	36.64	0.0272	1347	1

* Contains 95% of the total A2s and must be included per 49 CFR 173.433.
Radionuclides comprising less than 0.1% of the total A2s are not shown in the list.

D.11.4 200 g Source Term Without Polyurea

Performed By: Terry Vail
Checked By: John Woodbury

==================================== Input Information ====================================

Source Data:

Isotope	Ci	Bq	Gm
Pu-238	2.740E+00	1.014E+11	1.600E-01
Pu-239	1.040E+01	3.848E+11	1.677E+02
Pu-240	5.890E+00	2.179E+11	2.596E+01
Pu-241	2.270E+02	8.399E+12	2.204E+00
Pu-242	2.370E-04	8.769E+06	5.994E-02
Am-241	1.200E+01	4.440E+11	3.501E+00

Container Data:

Container Void Volume:	0.0702	m^3
Container Mass:	35.4	kg
Gamma Abs Curve:	85-Gal Drum	

Waste Data:

Waste Form:	Normal	
Waste State:	Solid	
Waste Volume:	0.252	m^3
Waste Mass:	363.1	kg
Mass of beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	kg
Waste Void Volume:	0	m^3

Decay Time Data:

Date to begin source decay:	1/1/1979
Date container sealed:	2/15/2007
Date container opened:	5/15/2012

G Value Materials Data:

Wt. Fraction	G Alpha	G Beta	G Gamma	Material Name
99.65	0	0	0	USER
0.25	0	0	3.2	Cellulose

G Value Data:

G Alpha	G Beta	G Gamma
0	0	0.008008

G values calculated from the list of materials (above).

Comments:
Gas generated by a 55 gallon drum with 200 g of 12% TRU without polyurea and placed in a 85-gallon overpack.

================================== Calculated Results ==================================

Decay Heat:

Heat Generated on Start Date:	1.006	W
Heat Generated on Seal Date:	1.146	W
Heat Generated on Open Date:	1.153	W

Hydrogen Gas:

H2 Concentration:	0.01	%	
H2 Moles :	0.0003209	moles	
H2 Volume :	7.193	cm^3	(0 C, 101.325 kPa)
H2 Rate on Seal Date:	0.0001551	cm^3/hr	(0 C, 101.325 kPa)
H2 Rate On Open Date:	0.0001576	cm^3/hr	(0 C, 101.325 kPa)

Helium Gas:

He Concentration:	0.012	%
He Moles :	0.000361	moles

He Volume :	8.091	cm^3	(0 C, 101.325 kPa)
He Rate On Seal Date:	0.0001754	cm^3/hr	(0 C, 101.325 kPa)
He Rate On Open Date:	0.0001764	cm^3/hr	(0 C, 101.325 kPa)

Pressure On Open Date:

Partial Pressure (H2):	0.01038	kPa	
Partial Pressure (He):	0.01168	kPa	
Partial Pressure (O2):	0.00519	kPa	(if H20 present in waste)
Total Pressure (H2 + He + Air):	101.3	kPa	
Total Pressure (H2 + He + O2 + Air):	101.4	kPa	(if H20 present in waste)

Transportation:
Note: Calculations are made at the end of the user-specified decay time.

Radioactive Determination:

Radioactive:	Yes		(ACEMs and ALECs > 1.0)
ACEM Limit Fraction:	3669000	ACEMs	(Number of ACEMs)
ALEC Limit Fraction:	348500000	ALECs	(Number of ALECs)

This package is not exempt from the HMR.

Effective A2s for Mixture:	0.06979	Ci

Type Determination:

Type:	B		(A2s > 1.0)
A2 Limit Fraction:	1347	A2s	(Number of A2s)

Limited Quantity Determination:

Limited Quantity:	No		(Activity > 0.001 A2)
Activity:	1347	A2	
	104.4	Ci	
	3.863	TBq	
U-235 Activity:	0.1332	gm	

The user must check ensure that all other requirements for LQ in 49 CFR 173.421 are met.

LSA Determination:

LSA-I:	No		(Fissile excepted, but A2s > 30 x rad limits)
LSA-II:	No		(A2s/gm > 0.0001)
LSA-III:	No		(A2s/gm > 0.002)
Specific Activity:	0.00371	A2/gm	
	0.0002876	Ci/gm	

The user must check ensure that all other requirements for LSA in 49 CFR 173.403 and 49 CFR 173.427 are met.

HRCQ Determination:

HRCQ:	No	
A2 Limit Fraction:	1347	A2s
Activity:	104.4	Ci
	3.863	TBq

Fissile Excepted Determination:

Fissile Excepted: Yes (Fissile isotopes <= 180 grams, solid non-fissile material > 3.365E+05 grams)

Fissile Quantity:	168.3	gm
Beryllium, lead, graphite, and hydrogenous material enriched with deuterium:	0	gm
Solid Non-Fissile Quantity:	398300	gm
Total Uranium Quantity:	0.2403	gm
U-233 Quantity:	8.212E-07	gm
U-235 Quantity:	0.1332	gm
Uranium Enrichment:	55.45	%
Total Plutonium Quantity:	194.2	gm
Pu-239 Quantity:	167.6	gm
Pu-241 Quantity:	0.5693	gm

Container Category Determination:

Container Category:	II

TRU Waste Determination:

TRU Waste:	Yes		(TRU activity > 100 nCi/gm)
TRU Activity:	97450	nCi/g	

WIPP Quantities:

FGE Value:	169.7
PE-Ci Value:	36.33

Reportable Quantity Determination:

Reportable Quantity:	Yes		(RQs >= 1.0)
RQ Limit Fraction:	3607	RQs	(Number of RQs)

Dose-Equivalent Curies:

Total ICRP-71/72 DE-Ci:	33.55
Total FGR-11 DE-Ci:	36.82

Source at the Start of Seal Time:

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Tl-209	1.442E-13	5.335E-03	3.526E-22
Tl-210	2.258E-14	8.356E-04	3.279E-23
Pb-209	6.676E-12	2.470E-01	1.448E-18
Pb-210	2.012E-11	7.444E-01	2.635E-13
Pb-211	2.048E-11	7.578E-01	8.297E-19
Pb-212	1.548E-15	5.727E-05	1.114E-21
Pb-214	1.075E-10	3.978E+00	3.280E-18
Bi-210	2.007E-11	7.425E-01	1.618E-16
Bi-211	2.048E-11	7.578E-01	4.987E-20
Bi-212	1.548E-15	5.727E-05	1.057E-22
Bi-213	6.676E-12	2.470E-01	3.448E-19
Bi-214	1.075E-10	3.979E+00	2.436E-18
Bi-215	1.665E-17	6.159E-07	1.408E-25
Po-210	1.866E-11	6.904E-01	4.153E-15
Po-211	5.592E-14	2.069E-03	5.396E-25
Po-212	9.914E-16	3.668E-05	5.589E-33
Po-213	6.533E-12	2.417E-01	5.180E-28
Po-214	1.075E-10	3.978E+00	3.365E-25
Po-215	2.048E-11	7.579E-01	6.948E-25
Po-216	1.548E-15	5.728E-05	4.298E-27
Po-218	1.075E-10	3.979E+00	3.803E-19
At-215	8.193E-17	3.031E-06	1.561E-31
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At-218	2.151E-14	7.958E-04	6.650E-25
At-219	1.716E-17	6.349E-07	1.799E-26
Rn-217	8.012E-16	2.965E-05	8.322E-30
Rn-218	2.151E-17	7.958E-07	1.455E-29
Rn-219	2.048E-11	7.579E-01	1.575E-21
Rn-220	1.548E-15	5.728E-05	1.679E-24
Rn-222	1.075E-10	3.979E+00	6.994E-16
Fr-221	6.677E-12	2.470E-01	3.846E-20
Fr-223	2.860E-13	1.058E-02	7.395E-21
Ra-223	2.048E-11	7.579E-01	3.999E-16
Ra-224	1.548E-15	5.728E-05	9.615E-21
Ra-225	6.706E-12	2.481E-01	1.710E-16
Ra-226	1.077E-10	3.985E+00	1.090E-10
Ra-228	1.965E-15	7.271E-05	7.208E-18
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Ac-227	2.073E-11	7.668E-01	2.866E-13
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Th-228	1.550E-15	5.736E-05	1.892E-18
Th-229	6.750E-12	2.497E-01	3.174E-11
Th-230	2.613E-08	9.667E+02	1.268E-06
Th-231	2.879E-07	1.065E+04	5.417E-13

Th-232	3.398E-15	1.257E-04	3.099E-08
Th-234	1.030E-12	3.813E-02	4.451E-17
Pa-231	8.564E-11	3.169E+00	1.813E-09
Pa-233	1.369E-04	5.066E+06	6.598E-09
Pa-234	1.340E-15	4.956E-05	6.703E-22
Pa-234m	1.030E-12	3.813E-02	1.501E-21
U-233	7.911E-09	2.927E+02	8.212E-07
U-234	1.949E-04	7.212E+06	3.135E-02
U-235	2.879E-07	1.065E+04	1.332E-01
U-235m	1.039E+01	3.844E+11	3.377E-07
U-236	4.896E-06	1.812E+05	7.570E-02
U-237	1.438E-03	5.322E+07	1.762E-08
U-238	1.034E-12	3.826E-02	3.076E-06
Np-237	1.375E-04	5.088E+06	1.951E-01
Pu-238	2.194E+00	8.117E+10	1.281E-01
Pu-239	1.039E+01	3.845E+11	1.676E+02
Pu-240	5.873E+00	2.173E+11	2.588E+01
Pu-241	5.863E+01	2.169E+12	5.693E-01
Pu-242	2.370E-04	8.769E+06	5.993E-02
Am-241	1.692E+01	6.262E+11	4.938E+00
Total Activity:	1.044E+02	3.863E+12	
w/o Daughters:	9.401E+01	3.478E+12	

Shipping Papers and Labels:

	Isotope	Number of A2s	Fraction of A2s	Cumulative A2s	Cumulative Fraction of A2s
*	Am-241	626.8	0.4653	626.8	0.4653
*	Pu-239	384.9	0.2857	1012	0.751
*	Pu-240	217.5	0.1615	1229	0.9125
*	Pu-238	81.26	0.06032	1310	0.9728
	Pu-241	36.64	0.0272	1347	1

* Contains 95% of the total A2s and must be included per 49 CFR 173.433.
Radionuclides comprising less than 0.1% of the total A2s are not shown in the list.